SPECIAL REPORT 244

RADON POTENTIAL IN WESTERN SANTA CLARA COUNTY, CALIFORNIA

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CALIFORNIA GEOLOGICAL SURVEY
Department of Conservation

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RADON POTENTIAL IN WESTERN SANTA CLARA COUNTY, CALIFORNIA

By

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PG #4265

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EXECUTIVE SUMMARY

Radon is a radioactive gas formed by decay of small amounts of uranium and thorium naturally present in rock and soil. Sometimes radon gas can move from underlying soil and rock into homes, become concentrated in the indoor air, and pose a significant lung cancer risk to the residents. The U.S. Environmental Protection Agency (U.S. EPA, 2016) estimates indoor radon exposure results in 21,000 lung cancer deaths annually in the United States.

Between December 2015 and May 2016, the California Department of Public Health-Indoor Radon Program (CDPH-Indoor Radon Program) conducted an indoor-radon survey of 735 homes in Santa Clara County. The survey used short-term charcoal detectors. The contract laboratory directly informed survey participants or their test results. Survey test results range from less than 0.4 picocuries per liter (pCi/L), the reported detection limit, to 39.6 pCi/L. The latter test result is for a home basement measurement in San Jose. The U.S. EPA recommended radon action level is 4.0 pCi/L.

The CDPH-Indoor Radon Program had an additional 58 voluntary indoor-radon measurements for Santa Clara County in their records, dating between January 2012 and November 2015. They were suitable for use and were included in this study. The finalized Santa Clara County database contains 793 home radon data.

A radon potential zone map for Santa Clara County, California, was developed by the California Geological Survey (CGS) using:

- CDPH-Radon Program 2015-2016 Santa Clara County indoor-radon survey test data
- The United States Geological Survey (USGS) geologic maps of the Palo Alto (MF-2332), San Jose (OFR 98-795), and Monterey 30' X 60' quadrangles (southern Santa Clara County portion, OFR 97-710); previous California Geological Survey radon potential maps and reports, especially those for San Mateo and Santa Cruz Counties (SR-226 and SR-216)

Also consulted during map development were:

- The Oakland Museum of California San Francisquito Creek Watershed and Alluvial Fan Map (approximately 1:57,600-scale)
- The National Uranium Resource Evaluation (NURE) Program Airborne Survey Equivalent Uranium (eU) Data for Santa Clara County from the USGS
- The San Mateo County soil unit data and maps from the Natural Resources Conservation Service (NRCS)

The radon potential map development process involved using a geographic information system (GIS) to link indoor-radon and airborne eU data to county geologic and soil units. Geologic units were then ranked for radon potential based on the characteristics of their associated radon data. Four radon potential categories, defined by the percentage of survey data equal to or exceeding (≥) 4.0 pCi/L, were used to rank Santa Clara geologic units: high (≥ 20 percent), moderate (5.0 to 19.9 percent), low (< 5.0 percent) and unknown (for geologic units with few or no data). Geologic units with the same radon potentials were grouped together to define the radon potential zones for the Santa Clara County radon potential map (i.e., all high potential occurrences collectively define the high radon potential zone, etc.). Lack of indoor-radon data and eU data accuracy concerns prevented mapping of sparsely populated eastern Santa Clara County.

A final step in radon map development involved statistical comparison of indoor-radon data populations for the resulting radon potential zones which confirmed that each zone represents a distinct radon potential. Geologic unit radon potential estimates did not utilize eU data or soil data because of data accuracy concerns. However, statistical comparison of eU data populations for the finalized radon potential zones based on indoor-radon data (just described) did support the validity of these zones. Soil unit physical property data could not be used in estimating geologic unit radon potentials because it is not available in Santa Clara County urban areas.

Using the finalized radon potential zone map and 2010 U.S. Census data, 137,366 people are estimated to live in residences with indoor-air radon concentrations ≥ 4.0 pCi/L in Santa Clara County. An estimated 22,619 people live in homes that will likely test ≥ 10 pCi/L, and about 6,691 people are estimated to live in homes that will likely test ≥ 20 pCi/L. Indoor-radon testing should be encouraged in Santa Clara County in high and moderate radon potential zone areas, which represent 10.2 percent of the county area, and within unknown potential areas where insufficient data are currently available to estimate radon potential. Almost 11 percent of the county's CDPH radon survey data ≥ 4.0 pCi/L are associated with the San Francisquito Creek alluvial fan (the Palo Alto and Stanford University area). The portion of the San Francisquito Creek alluvial fan within Santa Clara County only occupies about 0.7 percent of the county's land area. The CGS 2014 San Mateo radon study found 40 percent of that county's ≥ 4.0 pCi/L data associated with the San Francisquito Creek alluvial fan. Consequently, indoor-radon testing should be encouraged in homes and buildings within the San Francisquito Creek alluvial fan, and its watershed areas.

Those considering new home construction, particularly within high radon potential areas, may wish to consider radon resistant new construction practices. Post construction radon mitigation is possible, if necessary, but will be more expensive than the cost of adding radon reducing features during home construction. Homes with basements tend to have increased incidence of indoor-radon concentrations exceeding the U.S. EPA action level. Over 30 percent of the basements tested during the CDPH-Indoor Radon Program Santa Clara County survey exceeded the U.S. EPA action level. Radon testing of existing basements in Santa Clara County should be encouraged and radon-resistant new construction practices should be considered for basement additions to existing homes.

INTRODUCTION

Purpose

This report documents the data and procedures used by the California Department of Conservation, California Geological Survey (CGS) to develop the 2017 radon potential zone map for western Santa Clara County. CGS produced the map for the California Department of Public Health-Indoor Radon Program (CDPH-Indoor Radon Program) through an interagency agreement. The report includes radon potentials for individual geologic units and estimates of the county population exposed to 4 picocuries per liter (pCi/L) or higher indoor-radon concentrations. The report contains only minimal radon background, health, and testing information. No information on radon remediation of homes and buildings is included in the report.

The following websites have information about radon, related health issues, testing, and remediation:

http://www.cdph.ca.gov/healthinfo/environhealth/Pages/Radon.aspx

http://www.epa.gov/radon/pubs/index.html.

Background Information About Radon and Health

Radon gas is a naturally occurring odorless and colorless radioactive gas. It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. The average uranium content for the earth's continental crust is about 2.5 - 2.8 parts per million (ppm). Typical concentrations of uranium and thorium for many rocks and soils are a few ppm. Certain rock types, such as organic-rich shales, some granitic rocks, and silica-rich volcanic rocks may have uranium and thorium concentrations of five to several tens of ppm and occasionally higher. All buildings have some potential for elevated indoor-radon levels because radon is always present in the underlying soils and rocks. Buildings located on rocks and soils containing higher concentrations of uranium often have an increased likelihood of elevated indoor-radon levels. Breathing air with elevated radon gas over long periods increases one's risk of developing lung cancer. Not everyone exposed to radon will develop lung cancer. However, the U.S. Environmental Protection Agency (U.S. EPA, 2012) estimated 21,000 people die in the United States annually from lung cancer caused by radon exposure.

Indoor-radon concentrations are reported in pCi/L in the United States. The average indoor-radon concentration in American homes is about 1.3 pCi/L (U.S. EPA, 2012). Average outdoor air radon concentration is about 0.4 pCi/L. The U.S. EPA recommends that individuals avoid long-term exposures to radon concentrations ≥ 4.0 pCi/L (*4.0 pCi/L is the U.S. EPA recommended indoor-radon action level*). Based on long-term radon test statistics, the U.S. EPA estimates about one in 15 homes (6.7 percent) in the United States has radon levels ≥ 4.0 pCi/L.

Indoor-radon concentration is used as a guide for determining potential exposure and for identifying buildings that require remedial action. However, it is inhalation of two radon decay products, polonium-218 and polonium-214, that most likely leads to lung cancer. These polonium isotopes have very short half-lives (see Table 1). When they enter the lungs, they attach to lung tissue or trapped dust particles and quickly undergo radioactive decay, emitting high-energy alpha particles. The alpha particles are thought to damage the DNA in lung tissue cells, causing cancer (Brookins, 1990). In contrast, most longer-lived radon-222 is exhaled before undergoing radioactive decay.

Radon gas readily moves through rock and soil along micro-fractures and interconnected pore-spaces between mineral grains. Radon movement away from its site of origin is typically limited to a few feet to tens of feet because of the relatively short half-lives of radon isotopes (3.8 days for radon-222, 55.6 seconds for radon-220, and 3.96 seconds for radon-219), but movement may be hundreds of feet in some cases. Additional conditions, such as soil moisture content, also affect how far radon can move in the subsurface. Because radon-222 (a radioactive-decay product of uranium-238, see Table 1) has the longest half-life of the several radon isotopes, it is usually the predominant radon isotope in indoor air rather than shorter-lived radon-220 (a radioactive-decay product of thorium-232) or radon-219.

Radon gas moves from underlying soil into a building when air pressure inside the building is lower than air pressure in the soil, and pathways for radon entry into the building are available. Heating indoor air, using exhaust fans, and wind blowing across a building will all lower a building's internal air pressure. Pathways include cracks in slab foundations or basement walls, pores and cracks in concrete blocks, through-going floor-to-wall joints, and openings around pipes. Because radon enters buildings from the adjacent soil, indoor-radon concentrations are typically highest in basements and ground floor rooms. Radon can also enter a building in water from private wells. All ground water contains some dissolved radon gas. The travel time of water from an aquifer to a home in a private well is usually too short for much radon decay, so radon is available to be released in the house during water usage, for example through use of a bathroom shower. However, normal water usage typically adds only about 1.0 pCi/L of radon to indoor air per 10,000 pCi/L of radon in water (Grammer and Burkhart, 2004).

The most common indoor-radon testing methods utilize either charcoal (for 2 to 3 day short-term tests) or alpha-track type detectors (for 90-day to one-year long tests). These tests are simple to perform, inexpensive, and homeowners can do this testing. Homeowners expose the radon detector following manufacturer instructions and then send it to a laboratory for analysis, which is included in the detector cost. Typical turnaround time for test results from the laboratory is one to two weeks. Alternatively, one may hire professional certified radon testers to do the testing. The CDPH-Indoor Radon Program maintains lists of currently certified radon testers, mitigators, and laboratories on its website:
https://www.cdph.ca.gov/HealthInfo/environhealth/Pages/RadonServiceProviders.aspx

Nuclide (Isotope)	**Principal mode of radioactive decay**	**Half-life**
Uranium-238	Alpha	4.5 X 10^9 years
Thorium-234	Beta	24.1 days
Protactinium-234	Beta	1.2 minutes
Uranium-234	Alpha	2.5 X 10^5 years
Thorium-230	Alpha	7.5 X 10^4 years
Radium-226	Alpha	1,602 years
Radon-222	**Alpha**	**3.8 days**
Polonium-218	Alpha	3.1 minutes
Lead-214	Beta	26.8 minutes
Astatine-218	Alpha	1.5 seconds
Bismuth-214	Alpha	19.9 minutes
Polonium-214	Alpha	1.6 X 10^{-4} seconds
Thallium-210	Beta	1.3 minutes
Lead-210	Beta	22.6 years
Bismuth-210	Beta	5.0 days
Polonium-210	Alpha	138.4 days
Thallium-206	Beta	4.2 minutes
Lead-206	Stable	Stable

Table 1. The Uranium-238 Radioactive Decay Series (Generalized-does not show branching or some short-lived isotopes). Modified from Appleton, 2013, p. 241)

Long-term tests have advantages over short-term tests. Longer exposure times “average out” short-term fluctuations in radon levels, such as those caused by daily and seasonal weather changes. In addition, long-term tests utilize open-house conditions with windows and doors open or shut based on residents' preferences. Short-term tests utilize closed house conditions to maximize radon concentration during the measurement period. Consequently, long-term measurements should more accurately represent a person's exposure to indoor-radon. However, short-term measurements are more common because of the shorter time required. Often, if a short-term indoor-radon test result is several pCi/L > 4.0 pCi/L, follow-up short-term and long-term tests will also be > 4.0 pCi/L (see Appendix D).

Radon Potential Map Characteristics, Use and Limitations

Radon potential maps developed by CGS for the CDPH-Indoor Radon Program show areas where geologic conditions create higher or lower likelihoods for homes > 4.0 pCi/L. Also shown are areas lacking sufficient data for radon potential determination. The number of individuals exposed to excessive radon levels for an area can be estimated using U.S. Census track data and a radon zone map.

Radon potential maps are advisory, not regulatory. Their purpose is to help guide federal, state and local government agencies and private organizations target and prioritize radon program activities and resources.

A building's location on the map does not indicate it has excessive indoor-radon levels. In addition to geology, local variability in soil permeability, climatic conditions, and factors such as home design, construction, condition, and usage preferences may influence indoor-radon levels. Testing is the only way to determine the radon concentration in a specific building or home accurately, regardless of the radon zone. All radon zones typically have some buildings and homes with indoor-radon levels ≥ 4.0 pCi/L as well as some with radon levels < 4.0 pCi/L.

Development of the Radon Potential Map for western Santa Clara County

The radon potential zone development process for western Santa Clara County utilized data from the following sources:

- Indoor-radon test data for 793 Santa Clara County homes, 735 from the 2015 to 2016 CDPH-Indoor Radon Program Santa Clara County indoor-radon survey, and 58 data from previous home tests conducted between January 2012 and November 2015

- National Uranium Resource Evaluation (NURE) Program Aeroradiometric Survey data for equivalent uranium (eU) for the San Francisco, San Jose and Monterey 1X2 degree quadrangles

- United States Geological Survey (USGS) 1:100,000-scale geologic maps for the Palo Alto and San Jose 30' X 60' quadrangles (MF-2332 and OFR 98-795) and the 1:48,000-scale Geology of Southernmost Santa Clara County, California (OFR 97-710)

- Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) databases and maps for Santa Clara County, Western Part (Ca 641) and Eastern Santa Clara Area, California (Ca 646)

- U.S. Census Bureau 2010 census block data for Santa Clara County, California

The radon potential map development steps were:

1) Group indoor-radon survey data by surficial geologic unit using a geographic information system (GIS)
2) Preliminarily assign geologic units to one of four radon potential categories based on the percentage of indoor-radon data at, or exceeding, 4.0 pCi/L (see step 7 for categories), the number and magnitude of indoor-radon data per unit exceeding 10.0 pCi/L, and the total number of data
3) Group airborne equivalent uranium (eU) data by surficial geologic unit using GIS
4) Rate geologic units as to their likelihood of having problem radon homes based on the percentage of NURE eU data ≥ 5.0-ppm uranium (twice the average crustal uranium abundance of 2.5 ppm)
5) Group indoor-radon survey data by NRCS soil unit using GIS
6) Review soil permeability, shrink-swell character, hydrologic soil group information for soil units and indoor-radon data to see if these soil characteristics relate to higher or lower indoor-radon concentration homes
7) Considering the results from steps 2, 4 and 6, Assign final radon potentials to all 30’ X 60’ quadrangle surficial geologic units in the Santa Clara county study area using percentages of short-term tests ≥ 4.0 pCi/L as follows:
    - High—20.0 percent or more ≥ 4.0 pCi/L indoor data
    - Moderate—5 to 19.9 percent ≥ 4.0 pCi/L indoor data
    - Low—0 to 4.9 percent ≥ 4.0 pCi/L indoor data
    - Unknown—units with insufficient data for estimating the percent of ≥ 4.0 pCi/L indoor data
8) Group surficial unit areas with similar radon potentials to form radon potential zones using GIS.
9) Statistically compare indoor-radon data populations for the high, moderate and low radon potential zones to confirm that each zone represents a distinct indoor-radon data population.

10) Estimate the number of people living in each radon zone by using GIS to compare the census tract data to the radon zones and estimate the number of people residing in homes ≥ 4.0 pCi/L.

The following sections of this report provide more details on data used and the results of steps 1 through 10.

Portions of radon potential zones with faults and shear zones often have increased potential for elevated indoor-radon concentrations because such features provide pathways for radon flow. However, the 1:100,000-scale western Santa Clara County radon potential zone map does not show fault and shear zone locations. Fractures less than an inch wide can be significant radon pathways. Accurate representation of such fractures on a 1:100,000-scale map is not possible. A feature must be at least 100-200 square feet in size to show on a map at this scale and the accuracy of that feature's location is commonly +/- tens to hundreds of feet. Additionally, soil and alluvium may obscure faults and shear zones, especially smaller ones, or prevent their precise location. Consequently, at 1:100,000-scale mapping, it is better to base radon testing priorities on zone designation rather than attempt to target fault and shear zone locations. Detailed investigations of indoor-radon and fault or shear zone relationships require use or development of 1:24,000 or more detailed scale geologic maps.

Western Santa Clara County Geology Digital Layer

CGS radon potential map development requires appropriate geologic maps at 1:100,000-scale or more detailed scales. Geologic maps at smaller scales (less detail) typically do not work well for radon mapping. This is because geologic units from smaller-scale maps are more likely to be a composite of multiple rock types, and each lithology may have a distinctly different radon potential. Ideal geologic maps for radon potential map development are those with geologic units having a dominant lithology with relatively narrow ranges of variation in chemical and physical properties.

Digital versions of the USGS Palo Alto and San Jose 30X60 minute geologic maps (MF-2332 and OFR 98-795) are available online and were downloaded and utilized in preparation of the western Santa Clara County radon potential map. A digital version of OFR 97-710, covering the southernmost portion of Santa Clara County, is not available online and its geologic units were digitized from a registered raster version by the author.

A Brief Note About Statistics

The Santa Clara County radon potential map preparation required comparisons of indoor-radon data populations, and uranium data populations, for individual geologic units or groups of geologic units to see if they were statistically different. The nonparametric Mann-Whitney rank sum test was used for these comparisons. Many Santa Clara County geologic unit radon and uranium data populations are not normally or lognormally distributed. Parametric statistical tests, such as the t-test, require normally distributed populations. Nonparametric tests, such as the Mann-Whitney rank sum test, do not have distribution requirements. Additionally, indoor radon and uranium data populations are censored (i.e., have a lower analytical detection limit). The nonparametric Mann-Whitney rank sum test is a valid, simple and better approach than substitution for missing data below the detection limit and using the t-test (Helsel, 2012).

WESTERN SANTA CLARA COUNTY SHORT-TERM INDOOR-RADON SURVEY AND OTHER INDOOR-RADON DATA

Overview

The CDPH-Indoor Radon Program conducted a radon survey of indoor radon in 735 homes in Santa Clara County between December 2015 and May 2016. Each survey participant received a free charcoal detector with instructions for placement and exposure. After exposure, participants mailed their detector to the Radon Program contract lab for measurement. The contract lab provided test results directly to survey participants within several weeks of detector receipt. The CDPH-Indoor Radon Program had an additional 58 voluntary indoor-radon measurements for Santa Clara County in their records, dating between January 2012 and November 2015, which were suitable for use and included in this study. The finalized database contains 793 home radon data.

The primary goal of the survey was to obtain sufficient indoor-radon data for homes located on specific geologic units to evaluate unit radon potentials. The percentage of homes exceeding the 4.0 pCi/L U.S. EPA recommended radon action level was used to evaluate geologic unit radon potential.

Figure 1 shows the geographic distribution of homes with radon measurements in western Santa Clara County used in this study. Areas of high and low survey sample densities reflect areas of high and low population densities in the county. Figure 2 shows the geographic distribution of the 82 survey homes with reported concentrations ≥ 4.0 pCi/L.

The CDPH-Indoor Radon Program survey found concentrations ranging from < 0.4 pCi/L, the reporting detection limit, to 39.6 pCi/L, the latter for a basement measurement in a home in San Jose. Table 2 provides test floor and test room information, and the name of the associated geologic unit for those homes with radon survey concentrations ≥ 10.0 pCi/L.

Table 3 summarizes CDPH-Indoor Radon Program survey results in western Santa Clara County by Zip Code and city/region. For comparison, Table 4 summarizes CDPH online radon database test data for Santa Clara County Zip Codes accumulated by CDPH since 1989. The CDPH online database does not include all the 2015-2016 Santa Clara County radon survey data in Table 3. Table 4 data cannot be used for evaluating the radon potential of geologic units because, for much of its data, the only available location information is the Zip Code for the house tested. More

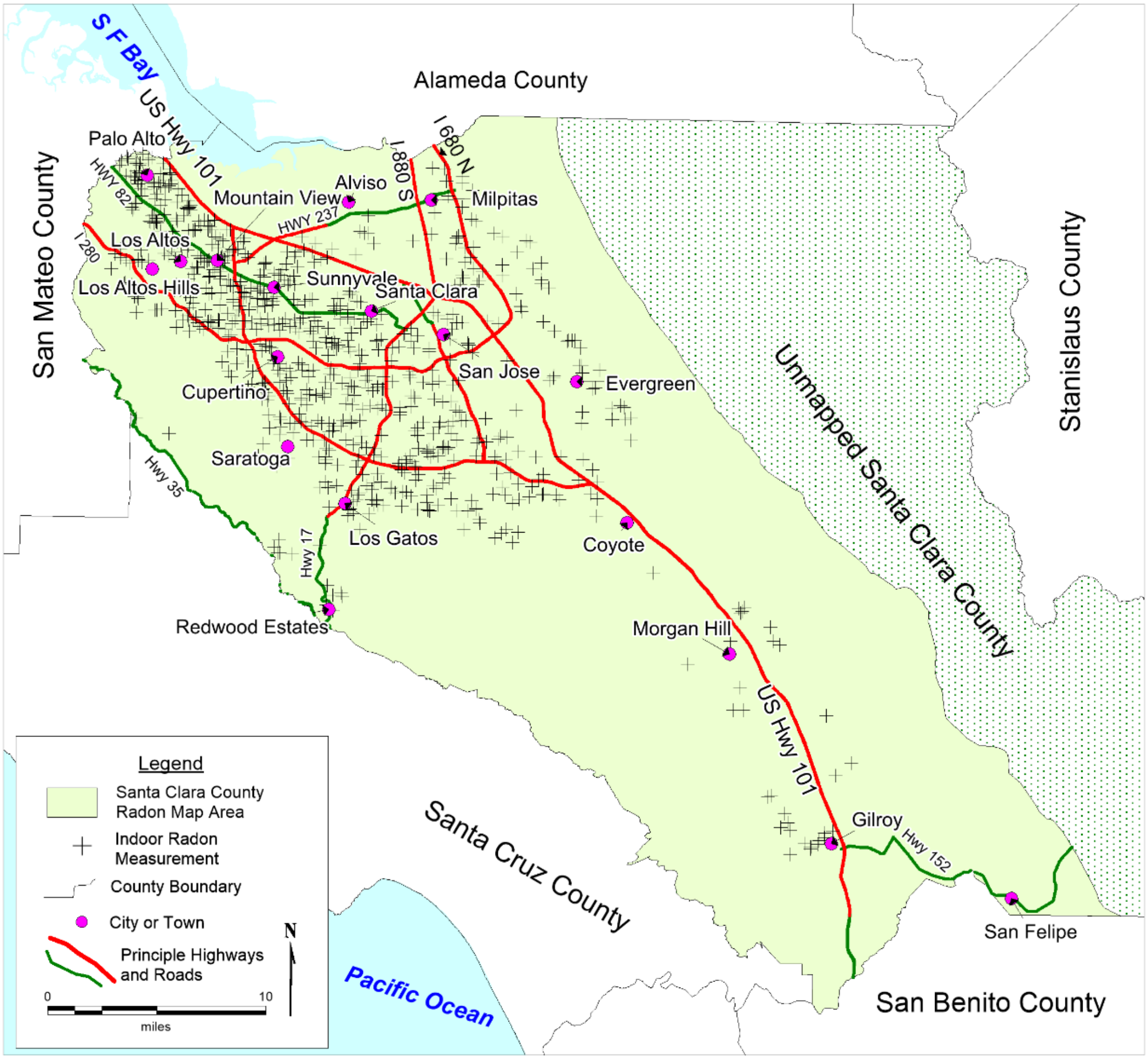
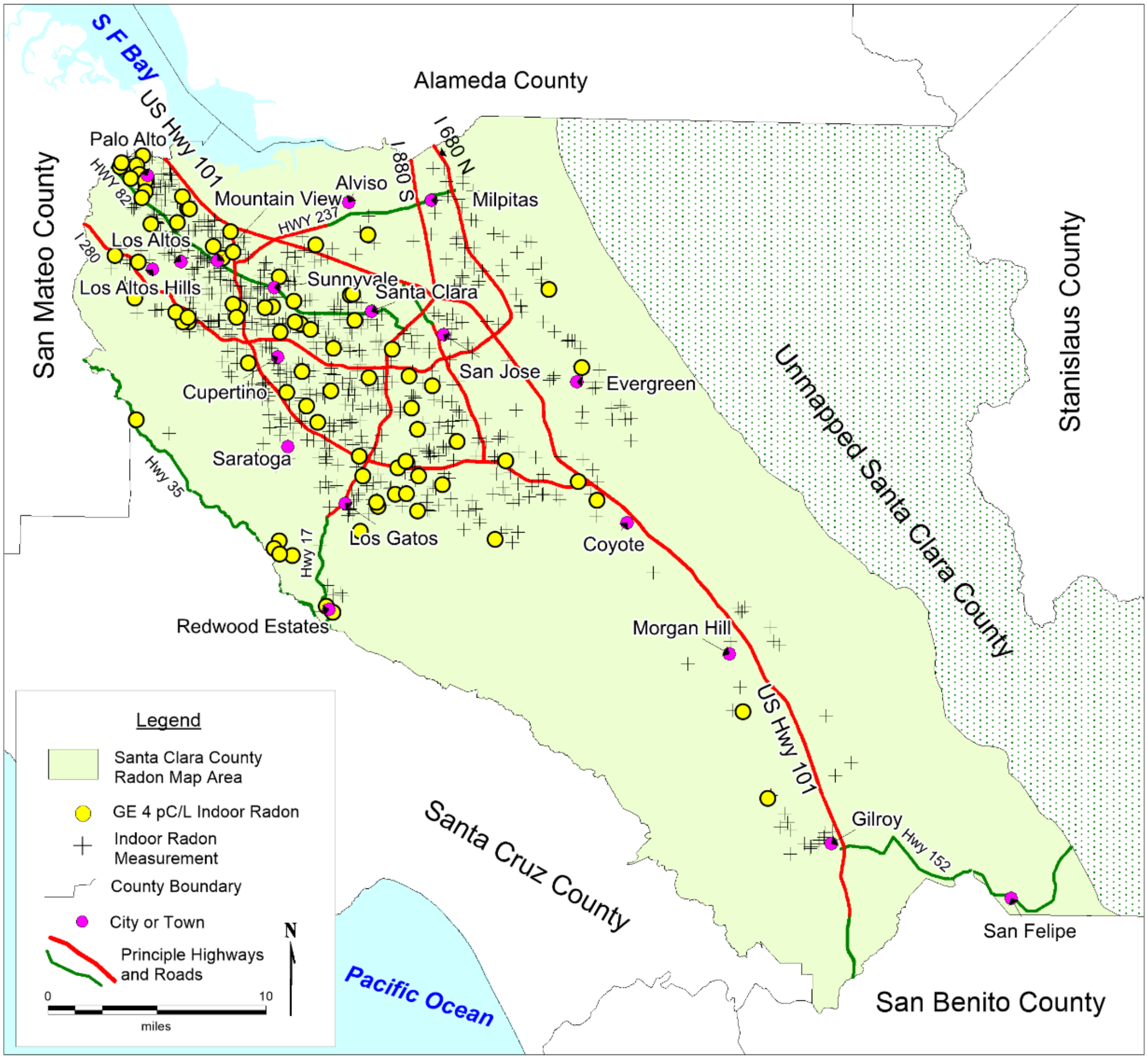


Figure 1. CDPH Indoor Radon Program Test Locations, Santa Clara County

precise test location information is needed for geologic unit radon potential evaluation. Another complication with Table 4 data is that it likely includes multiple radon measurements for some homes (e.g., follow-up measurements, simultaneous measurements in multiple rooms, or even measurements after radon mitigation) that cannot be identified as such. Despite these limitations, comparison of Zip Codes with 25 or more data in Table 3 and Table 4 often shows similar percentages of ≥ 4.0 pCi/L tests, maximums and suggestion of similar indoor-radon trends for Santa Clara County.

Table 5 shows that the percentage of ≥ 4.0 pCi/L radon data and the maximum radon concentration for basements are both significantly above those for other floors in Santa Clara County homes.



Note: GE = greater than or equal to

Figure 2. CDPH Indoor Radon Program test locations, Santa Clara County, with ≥ 4.0 pCi/L Sites Identified (shown as yellow circles)

Home	Radon pCi/L	Zip Code	City	Floor	Room	Surficial Geologic Unit
1	39.6	95125	San Jose	Basement	Basement	Qhf2-principal Holocene fans and associated terraces
2	24.5	95033	Los Gatos	1st Floor	Master Bedroom	Tsl-San Lorenzo Formation
3	24.5	95030	Los Gatos	Basement	Wine Cellar	fms-graywacke Marin Headlands terrane
4	19.0	94040	Mountain View	Basement	Basement	Qhaf-alluvial fan and fluvial deposits, Holocene
5	18.8	95033	Los Gatos	1st Floor	Study	Tsl-San Lorenzo Formation
6	16.2	94024	Los Altos	Basement	Bedroom	Tlad? -Ladera Sandstone (uncertain)
7	16.1	95070	Saratoga	1st Floor	Master Bedroom	Qhf2-principal Holocene fans and associated terraces
8	15.1	94301	Palo Alto	Basement	Under Stairs	Qpaf-alluvial fan and fluvial deposits, Pleistocene
9	14.9	95124	San Jose	1st Floor	*	Qpf—alluvial fan deposits, Upper Pleistocene
10	14.1	95051	Santa Clara	1st Floor	Office	Qhl-Levee deposits, Holocene
11	11.7	94022	Los Altos	1st Floor	Living Room	Tm-Monterey Formation
12	11.5	94301	Palo Alto	Basement	*	Qhfp-Floodplain deposits, Holocene
13	10.9	94024	Los Altos	1st Floor	Lower Level Family Room	Tm-Monterey Formation

* not provided by homeowner

Table 2. CDPH Indoor-radon Survey Data ≥ 10.0 pCi/L by Zip Code, Floor, Room, and Geologic Unit for Western Santa Clara County

Note: Geologic map unit symbols (e.g., Qhf2, Tsl etc.) referred to above are described in Appendix E.

Zip Code	City/Region	Number of Tests	Tests ≥ 4.0 pCi/L	% Tests ≥ 4.0 pCi/L	High pCi/L
94022	Los Altos, Los Altos Hills	36	3	8.3	11.7 (First floor living room)
94024	Los Altos, Los Altos Hills	42	5	11.9	16.2 (Basement bedroom)
94040	Mountain View	26	2	7.7	19.0 (Basement)
94041	Mountain View	11	2	18.2	4.7 (First floor garage)
94043	Mountain View	25	2	8.0	7.7 (First floor living room)
94085	Sunnyvale	11	0	0	2.4 (First floor living room)
94086	Sunnyvale	20	2	10.0	6.2 (First floor room not provided)
94087	Sunnyvale	44	6	13.6	9.0 (First floor dining room)
94089	Sunnyvale	3	1	33.3	6.9 (First floor dining room)
94301	Palo Alto	29	8	27.6	15.1 (Basement under stairs)
94303	Palo Alto	22	3	13.6	9.9 (First floor living room)
94304	Palo Alto	1	0	0	2.1 (First floor living room)
94306	Palo Alto	25	3	12.0	9.1 (First floor living room)
95008	Campbell	23	0	0	3.5 (First floor living room)
95009	Campbell	1	0	0	1.9 (First floor play room)
95014	Cupertino, Monte Vista	40	2	5.0	6.8 (Basement)
95020	Gilroy	19	1	5.3	5.4 (First floor great room)
95030	Los Gatos, Monte Sereno	11	1	9.1	24.5 (Basement wine cellar underground)
95032	Los Gatos	32	7	21.9	6.7 (First floor dining room)
95033	Los Gatos	13	7	53.9	24.5 (First floor master bedroom)
95035	Milpitas	10	0	0	2.3 (First floor bedroom)
95037	Morgan Hill	14	1	7.1	8.6 (First floor room not specified)
95046	San Martin	1	0	0	2.1 (First floor bedroom)
95050	Santa Clara	11	1	9.1	4.4 (First floor dining room)
95051	Santa Clara	30	3	10.0	14.1 (First floor office)
95054	Santa Clara	5	1	20.0	9.1 (First floor dining room)
95070	Saratoga	27	2	7.4	16.1 (First floor master bedroom)
95110	San Jose	2	0	0	3.4 (First floor bedroom)
95111	San Jose	2	0	0	1.2 (First floor living room)
95112	San Jose	10	0	0	1.7 (Basement “middle”)
95113	San Jose	1	0	0	0.5 (First floor stairs)
95116	San Jose	2	0	0	2.3 (First floor laundry room)
95117	San Jose	12	1	8.3	4.4 (First floor bedroom)
95118	San Jose	14	2	14.3	4.6 (First floor dining room)
95119	San Jose	3	0	0	3.9 (First floor living room)
95120	San Jose	19	1	5.3	4.4 (First floor living room)
95121	San Jose	2	0	0	2.4 (First floor living room)
95122	San Jose	1	0	0	2.1 (First floor “center”)
95123	San Jose	15	1	6.7	4.6 (First floor living room)
95124	San Jose	28	4	14.3	14.9 (First floor room not specified)
95125	San Jose	22	2	9.1	39.6 (Basement)
95126	San Jose	9	0	0	3.9 (Basement)

Zip Code	City/Region	Number of Tests	Tests ≥ 4.0 pCi/L	% Tests ≥ 4.0 pCi/L	High pCi/L
95127	San Jose	10	1	10.0	5.3 (First floor bedroom)
95128	San Jose	15	2	13.3	9.7 (First floor living room)
95129	San Jose	20	2	10.0	5.3 (First floor room not provided)
95130	San Jose	7	0	0	3.2 (First floor room not provided)
95131	San Jose	10	0	0	3.1 (First floor family room)
95132	San Jose	10	0	0	3.8 (First floor hall)
95133	San Jose	5	0	0	2.1 (Second floor “room”)
95134	San Jose	2	0	0	2.0 (First floor room not provided)
95135	San Jose	11	0	0	2.3 (First floor bedroom)
95136	San Jose	12	0	0	3.2 (First floor living room)
95138	San Jose	6	1	16.7	5.5 (First floor spare bedroom)
95139	San Jose	2	1	50.0	4.5 (First floor living room)
95148	San Jose	9	1	11.1	6.5 (First floor dining room)
All	Summary	793	82	10.3	39.6 (Basement)

Table 3. CDPH Indoor-radon Survey Data for the CDPH 2015-2016 Santa Clara County Survey—by Zip Code Zone

Zip Code	City/Region	Number of Tests	Tests ≥ 4.0 pCi/L	% Tests ≥ 4.0 pCi/L	High pCi/L
94022	Los Altos, Los Altos Hills	75	4	5.3	9.5
94023	Los Altos	6	0		1.2
94024	Los Altos, Los Altos Hills	59	3	5.1	16.2
94035	Mountain View, Moffett Field	0			
94039	Mountain View	7	1	14.3	7.4
94040	Mountain View	55	2	3.6	7.7
94041	Mountain View	14	0		1.6
94042	Mountain View	4	0		1.9
94043	Mountain View	51	2	3.9	4.5
94085	Sunnyvale	55	8	14.5	8.5
94086	Sunnyvale	46	5	10.9	10.8
94087	Sunnyvale	103	12	11.7	26.6
94088	Onizuka AFB	1	0		0.9
94089	Sunnyvale	15	0		3.3
94301	Palo Alto	78	18	23.1	16.5
94302	Palo Alto, East Palo Alto	2	1	50.0	14.9
94303	Palo Alto	30	0		3.4
94304	Palo Alto	5	0		1.7
94305	Palo Alto, Stanford	14	1	7.1	6.9
94306	Palo Alto	65	8	12.3	6.7
94309	Palo Alto, Stanford	0			
95002	Alviso	1	0		0.6
95008	Campbell	61	4	6.6	5.4
95009	Campbell	0			

Zip Code	City/Region	Number of Tests	Tests ≥ 4.0 pCi/L	% Tests ≥ 4.0 pCi/L	High pCi/L
95011	Campbell	0			
95013	Coyote	0			
95014	Cupertino, Monte Vista, Permanente	93	4	4.6	38.3
95015	Cupertino	0			
95020	Gilroy	30	1	3.3	4.6
95021	Gilroy	0			
95026	Holy City	0			
95030	Los Gatos	37	7	18.9	14.7
95031	Los Gatos	2	0		1.0
95032	Los Gatos	54	3	5.6	5.5
95033	Los Gatos	188	65	34.6	57.2
95035	Milpitas	44	0		3.1
95036	Milpitas	0			
95037	Morgan Hill	35	2	5.7	33.4
95038	Morgan Hill	2	0		0.8
95042	New Almaden	0			
95044	Redwood Estates	0			
95046	San Martin	7	2	28.6	737.5
95050	Santa Clara	40	6	15.0	9.8
95051	Santa Clara	63	0		3.3
95052	Santa Clara	0			
95054	Santa Clara	16	1	6.3	4.3
95055	Santa Clara	0			
95056	Santa Clara	14	0		1.2
95070	Saratoga	108	12	11.1	7.2
95071	Saratoga	1	0		2.3
95101	San Jose	0			
95103	San Jose	0			
95106	San Jose	0			
95108	San Jose	2	0	0	0
95109	San Jose	0			
95110	San Jose	10	1	10.0	4.4
95111	San Jose	9	0		2.0
95112	San Jose	31	1	3.2	12.7
95113	San Jose	6	0		0.8
95115	San Jose	0			
95116	San Jose	7	0		2.1
95117	San Jose	31	4	12.9	11.4
95118	San Jose	37	3	8.1	6.1
95119	San Jose	7	0		1.6
95120	San Jose	55	5	9.1	10.8
95121	San Jose	10	0		2.7
95122	San Jose	10	0		3.1
95123	San Jose	54	1	1.9	4.8
95124	San Jose	42	2	4.8	4.3
95125	San Jose	106	14	13.2	39.6

Zip Code	City/Region	Number of Tests	Tests ≥ 4.0 pCi/L	% Tests ≥ 4.0 pCi/L	High pCi/L
95126	San Jose	62	1	1.6	9.3
95127	San Jose	26	2	7.7	9.0
95128	San Jose	29	3	10.3	5.5
95129	San Jose	33	0		3
95130	San Jose	9	0		3.2
95131	San Jose	37	0		2.5
95132	San Jose	21	0		2.2
95133	San Jose	5	0		2.1
95134	San Jose	10	0		3.1
95135	San Jose	12	0		3.1
95136	San Jose	7	0		2.6
95138	San Jose	21	0		1.3
95139	San Jose	9	1	11.1	4.9
95140	San Jose, Mount Hamilton	2	0		1.2
95141	San Jose	0			
95142	San Jose	0			
95148	San Jose	17	0		2.9
95150	San Jose	1	1	100.0	7.5
95151	San Jose	1	1	100.0	5.6
95152	San Jose	0			
95153	San Jose	2	0		0
95154	San Jose	0			
95155	San Jose	0			
95156	San Jose	0			
95157	San Jose	0			
95158	San Jose	1	0		0
95159	San Jose	0			
95160	San Jose	2	0		3.0
95161	San Jose	0			
95164	San Jose	3	0		0.8
95170	San Jose	0			
95172	San Jose	0			
95173	San Jose	0			
All	Summary	2208	212	9.6	

Table 4. Radon Test Results for Santa Clara County Zip Code Zones from the CDPH Radon Zip Code Database for California (as of February, 2016).

Floor	N	N ≥ 4	% ≥ 4	High
Basement	49	18	36.7	39.6
First Floor	710	61	8.6	24.5
Second Floor	14	1	7.1	5.2
Not Specified	20	2	10.0	5.0
Total Tests and Percent % ≥4	793	82	10.3	39.6

Table 5. Comparison of Radon Survey Data by Building Floor

Radon Survey Data—Exposure Duration and Data Quality

Santa Clara County CDPH Indoor Radon Program survey participants exposed their charcoal radon test kits for two days (252 homes), three days (428 homes) or four days (113 homes). Differences between two-day, three-day or longer test results should be negligible. Appendix A lists results for 96 concurrent (duplicate) tests. Table 6 summarizes these test results and shows consistency between simultaneous measurements in the same room on the same floor. Review of Appendix A also provides a sense of the magnitude of radon variability between different rooms on the same floor and between rooms on different floors.

Number of Pairs	**High Measurement Group Range pCi/L**	**Associated Concurrent Group Measurement Ranges pCi/L**	**Differences pCi/L**
2	5.6-8.7	5.1-7.1	0.5-1.6
18	2.1-4.7	1.5-4.1	0.0-0.9
5	1.5-1.9	1.2-1.5	0.2-0.7

Table 6. Summary of Concurrent Indoor-radon Test Data for Santa Clara County

Appendices B and C show the analytical results for three field blank radon detectors (i.e., not exposed to radon) and 88 spiked radon detectors (exposed to a known concentration of radon), respectively.

Appendix B shows the analytical results for 211 detector blanks, analyzed in batches on 01/06/2016, 02/04/2016, 02/23/2016, 03/19/2016, 04/14/2016, and 05/16/2016. The analytical results are typical of background ambient air radon concentrations in the United States, the average of which is 0.4 pCi/L.

Appendix C shows the analytical results for detectors exposed to known concentrations of radon in a laboratory radon chamber. The detectors were exposed, in batches, to the following radon concentrations: 10.3 pCi/L (for 96 hours), 13.2 pCi/L (for 72 hours), 24.3 pCi/L (for 48 hours), 25.5 pCi/L (for 96 hours) and 34.9 pCi/L (for 72 hours). The related exposure dates are available in Appendix C. Eighty-four percent of the 88 laboratory spike samples differed from the average radon chamber radon concentrations by less than 10 percent. Only one sample differed by more than 15 percent.

In summary, duplicate, blank and spiked sample test results support the validity of the CDPH-Indoor Radon Program's Santa Clara County radon survey data.

Follow-up Radon Testing Results

Appendix D compares 12 follow-up radon measurements for the same room and floor as the initial survey measurements in 7 different homes. The time between original and follow-up measurements range from 20 to 164 days. The highest measurement in Appendix D, a basement concentration of 39.6 pCi/L, tested 43 days before at 19.9 pCi/L. Five initial measurements above 4.0 pCi/L all had follow-up measurements exceeding 4.0 pCi/L. These results confirm the magnitude of the first test and show that elevated radon concentrations likely exist over significant periods in certain rooms of these homes. Rooms in one home with initial radon tests ranging in radon concentrations from 2.5 to 3.9 pCi/L tested 20 to 25 days later at 4.1 to 4.5 pCi/L. A house with a first-floor room initially testing at 2.0 pCi/L in December tested at 1.3 pCi/L 112 days later. Follow-up measurements show that initial tests above 4.0 pCi/L can have follow-up tests months later that still exceed 4.0 pCi/L. A house with rooms initially testing from 2.5 pCi/L to 3.9 pCi/L may have follow-up tests a few weeks later that slightly exceed 4.0 pCi/L. A room in a home initially testing at 2.0 pCi/L can still test well below 4.0 pCi/L 3 months later.

WESTERN SANTA CLARA COUNTY GEOLOGIC UNIT RADON POTENTIALS

Indoor-Radon Data and Geologic Units

The 2015-2016 CDPH-Indoor Radon Program survey for western Santa Clara County obtained radon data for homes located on 37 different geologic map units. These geologic units are depicted on the USGS 1:100,000-scale geologic maps for the Palo Alto and San Jose 30’ X 60’ quadrangles (MF-2332 and OFR 98-795), and the Geology of Southernmost Santa Clara County, California (OFR 97-710). GIS software was used to determine which geologic unit is present at each radon test location.

The names of geologic units within the Santa Clara radon map area, and their symbols (e.g., Qpaf, Qhl, Tm, Tsl, etc.), are listed in Appendix E. The availability of indoor-radon survey data for each geologic unit is also indicated in Appendix E. Appendix F summarizes radon survey data for the 37 geologic units with survey data. Appendix F shows the number of homes with radon data, the actual measurements, and the mean, median, low, and high radon data in pCi/L, and percentage ≥ 4.0 pCi/L data for each geologic unit.

Preliminary Geologic Unit Radon Potentials Based Upon Indoor-Radon Data

Preliminary radon potentials were assigned to geologic units based on their associated indoor-radon data, listed in Appendix F, and the radon potential definitions in step 7 on page 5. Tables 7, 8 and 9 list geologic units likely to have high, moderate, or low radon potential respectively. Some of the unit radon potentials listed in these tables are provisional—less certain because they have less than 25 indoor-radon data. Radon potentials previously assigned to geologic units in Santa Cruz County (Churchill, 2010) and San Mateo County (Churchill, 2014) were also considered in assigning provisional radon potentials to geologic units in Santa Clara County. Provisional radon potential status is indicated in Tables 7, 8 and 9 as follows: “High (P)”, “Moderate (P)”, or “Low (P)”. Appendix G lists geologic units designated as having “Unknown” radon potential due to insufficient data available for radon potential assignment.

Surficial (alluvial) Geologic Units—Preliminary Radon Potentials

The dominant geomorphic features of Santa Clara County are the Santa Clara Valley, bounded by the Santa Cruz Mountains on the southwest, the Diablo Range on the east and San Francisco Bay on the north. Alluvial material for Santa Clara Valley surficial deposits is derived from geologic units in the Santa Cruz Mountains and the Diablo Range. The densely-populated Santa Clara Valley consists of several unconsolidated surficial geologic units. These units are associated with alluvial fans, natural levee deposits, stream channel deposits, flood plain deposits, basin deposits, and bay mud. Typically, surficial geologic units are identified and mapped based on sediment physical characteristics and geomorphic feature association, not the sediment's parent rock type or chemistry. However, parent rock type and chemistry strongly relate to a surficial unit's radon potential. Consequently, different occurrences of a surficial unit within a geologic map may have different radon potentials because of differences in type and abundance of source rocks in their associated watersheds. Geologic maps do not indicate such differences for surficial units.

Bedrock geologic units with moderate or high radon potential (radon source rocks) that occur in upland areas in Santa Clara County are present within some watersheds and absent in others. To test the significance of watershed radon source rock presence for radon potential in downstream alluvial deposits, radon survey data were first grouped by surficial unit for different geomorphic alluvial features. The presence or absence of known or likely radon source rocks in their associated watersheds was noted. Next, radon potentials were assigned to the occurrences based on the percentage of data ≥ 4.0 pCi/L. Tables 7, 8 and 9 show the results of this process. Note that occurrences of some surficial units have different radon potentials at different locations. This supports the hypothesis that radon source rock presence or absence in upland watershed areas is an important controlling factor for radon potentials in downstream alluvial deposits.

The San Francisquito Creek forms a boundary between Santa Clara and San Mateo counties and its alluvial fan is present in both counties. The Santa Clara County portion of the alluvial fan is indicated by the high radon potential area (in red) adjacent to the San Francisquito Creek Fan Area label on Figures 3 and 4 below. San Francisquito Creek is the largest stream on the western margin of San Francisco Bay and drains a watershed of 37 square miles (Sowers, 2004). During thousands of years the creek built up an alluvial fan radiating out to the northeast from where it exits the hills near the intersection of Alpine Road and Junipero Serra Boulevard. Portions of Menlo Park, Atherton, and East Palo Alto in San Mateo County and Palo Alto and the Stanford University campus in Santa Clara County are located on the fan. Churchill (2014) found that about 40 percent of the residences tested in the CDPH Indoor Radon Program survey for San Mateo County that were ≥ 4.0 pCi/L for San Mateo County were located on this alluvial fan.

The San Mateo County portion of the San Francisquito Creek alluvial fan composed of alluvial units Qhaf, Qhfp, Qhl, Qpaf, and Qpoaf was assigned high radon potential. It received this assignment because 36.6 percent of the indoor-radon data within the combined area of these units exceed 4.0 pCi/L (Churchill, 2014). Qhb alluvial unit areas within the San Mateo portion of the fan were assigned low radon potential based on five indoor-radon data, all under 4.0 pCi/L. The San Francisquito alluvial fan is entirely within the USGS Palo Alto 30X60 minute geologic map (MF-2332) so the geologic unit definitions within the fan are the same in both San Mateo and Santa Clara counties.

Table 7 shows CDPH radon survey results for occurrences of alluvial units Qhfp, Qhl and Qpaf in the San Francisquito Creek alluvial fan within Santa Clara County (see San Francisquito Alluvial Fan (PA) entry in Table 7). These occurrences were designated as provisionally high radon potential because 37.5 percent of the indoor-radon data within the combined area of these units exceed 4.0 pCi/L. This is similar to the 36.6 percentage previously mentioned for the San Mateo County portion of the fan (Churchill, 2014). There are no high radon potential areas for units Qhfp, Qhl and Qpaf outside of the San Francisquito Creek alluvial fan within Santa Clara County. Note that Qpf, the equivalent of Qpaf in the San Jose 30X60 minute geologic map (USGS OFR 98-795), has preliminary radon potential designations of moderate and low but not high (see Tables 7, 8, and 9).

The upper portion of the San Francisquito Creek Alluvial Fan (i.e., the southwestern most portion) consists of surficial unit Qpoaf. No indoor-radon data are available for this portion of the alluvial fan or for other Qpoaf areas in Santa Clara County. The CDPH Indoor Radon Program survey of San Mateo County yielded four data on the Qpoaf portion of the fan in that county, with one exceeding 4.0 pCi/L (6.9 pCi/L; Churchill, 2014). Consequently, because of limited indoor-radon data in San Mateo County and no indoor data in Santa Clara County, the upper Qpoaf area of the San Francisquito alluvial fan within Santa Clara County has been provisionally designated as having moderate radon potential to error on the side of caution and encourage additional indoor-radon testing here. If sufficient indoor-radon data for this unit/area become available in the future its radon potential status may change. For additional details about the geology and radon potential of the San Francisquito Creek alluvial fan see Churchill, 2014 (pp. 19-23).

East of the San Francisquito Creek alluvial fan, indoor-radon data support either moderate or low radon potentials for Qhfp, Qhl, Qpaf, Qhaf, Qhb and Qhp occurrences, depending on their locations and geomorphic feature association. Note that Tables 7, 8, and 9 also show high, moderate, and low radon potentials for bedrock geologic units which are discussed in the following section.

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
Qhfp (PA) Holocene flood plain deposits; unit in San Francisquito alluvial fan	R = 50.0%? N = 2 N ≥ 4.0 pCi/L = 2 Maximum = 11.5 pCi/L	High (P) Location adjacent to other high potential units; watershed has significant radon source rocks
Qhl (PA) Holocene natural levee deposits; unit in San Francisquito alluvial fan	R = 50.0%? N = 6 N ≥ 4.0 pCi/L = 3 Maximum = 6.4 pCi/L	High (P) Location adjacent to other high potential units; watershed has significant radon source rocks
Qpaf (PA) Pleistocene alluvial fan and fluvial deposits; unit in San Francisquito alluvial fan	R = 25%? N = 16 N ≥ 4.0 pCi/L = 4 Maximum = 15.1 pCi/L	High (P) Location adjacent to other high potential units; watershed has significant radon source rocks
San Francisquito alluvial fan (PA) combined alluvial units' radon data (Qhfp, Qhl and Qpaf)	R = 37.5% N = 24 N ≥ 4.0 pCi/L = 9 Maximum = 15.1 pCi/L	High Equivalent geologic units in San Mateo Co. portion of San Francisquito alluvial fan have high potential; San Francisquito Creek watershed upland areas have significant radon source rocks
Tm (PA) and **Tms (SJ)** Monterey Formation	R = 34.5% N = 29 N ≥ 4.0 pCi/L = 10 Maximum = 11.7 pCi/L	High (R* ≥ 20%) Similar potential to occurrences in San Mateo and Santa Cruz Counties classified as high radon potential
Tsl (PA) San Lorenzo Formation	R = 75%? N = 4 N ≥ 4.0 pCi/L = 3 Maximum = 24.5 pCi/L	High (P) Similar potential to occurrences in San Mateo and Santa Cruz Counties classified as high radon potential
Tsr ls (SJ) Landslide in Rices Mudstone Member-San Lorenzo Formation	R = 100%? N = 2 N ≥ 4.0 pCi/L = 2 Maximum = 9.8 pCi/L	High (P) Similar potential to occurrences in San Mateo and Santa Cruz Counties classified as high radon potential
	N=60	

Table 7. High Radon Potential Geologic Units in Santa Clara County Based on 2015-2016 CDPH Short-term Indoor-radon Data

(P)=Unit radon potential is provisional (less certain) because unit has significantly fewer than 25 tests; R* = (number data ≥ 4.0 pCi/L ÷ total data) X 100; (PA)=Palo Alto 30X60 minute quadrangle; (SJ)=San Jose 30X60 minute quadrangle.

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
Qhaf (PA) Holocene alluvial fan and fluvial deposits	R = 10.1% N = 79 N ≥ 4.0 pCi/L = 8 Maximum = 19.0 pCi/L	Moderate (R* = 5.0 to 19.9%) Watershed has some radon source rocks
Qhb (PA and SJ) Holocene basin deposits (excluding Qhb within the San Francisquito Alluvial Fan)	R = 14.0% N = 57 N ≥ 4.0 pCi/L = 8 Maximum = 9.9 pCi/L	Moderate (R* = 5.0 to 19.9%) Distal and downslope from moderate radon potential fan
Qhf2 (SJ) Alluvial fan deposits-older, principal Holocene fans and associated terraces	R = 9.4% N = 107 N ≥ 4.0 pCi/L = 10 Maximum = 39.6 pCi/L	Moderate (R* = 5.0 to 19.9%) Watershed has some radon source rocks
Qhfp (PA and SJ) Holocene flood plain deposits (excluding Qhfp within the San Francisquito Alluvial Fan)	R = 33.3% N = 6 N ≥ 4.0 pCi/L = 2 Maximum = 4.7 pCi/L	Moderate (P) NW part of county where watersheds have more radon source rocks
Qhl (PA and SJ) Holocene natural levee deposits (excluding Qhfp within the San Francisquito Alluvial Fan)	R = 18.2% N = 33 N ≥ 4.0 pCi/L = 6 Maximum = 14.1 pCi/L	Moderate (R* = 5.0 to 19.9%) Along edges of moderate Rn potential alluvial fans and basins
Qpaf (PA) Pleistocene alluvial fan and fluvial deposits (excluding Qhfp within the San Francisquito Alluvial Fan)	R = 8.9% N = 79 N ≥ 4.0 pCi/L = 7 Maximum = 9.2 pCi/L	Moderate (R* = 5.0 to 19.9%) Watershed has some radon source rocks
Qpf (SJ) Upper Pleistocene alluvial fan deposits	R = 16.2% N = 37 N ≥ 4.0 pCi/L = 6 Maximum = 14.9 pCi/L	Moderate (R* = 5.0 to 19.9%) Watershed has some radon source rocks
Tcc (SJ) Upper and middle Miocene Claremont Formation	R = %? N = 2 N ≥ 4.0 pCi/L = 1 Maximum = 5.3 pCi/L	Moderate (P) Similarities to Monterey Fm. (siliceous shale)
Tlad (PA) Upper? And middle Miocene Ladera Sandstone	R = 33.3% N = 3 N ≥ 4.0 pCi/L = 1 Maximum = 4.5 pCi/L	Moderate (P) Components like Monterey Fm. (porcelaneous shale)
Tms-PA (PA) Unnamed marine sandstone and shale with minor interbeds of siliceous mudstone and semi-siliceous shale	R = 50.0% N = 2 N ≥ 4.0 pCi/L = 1 Maximum = 16.2 pCi/L	Moderate (P) Components like Monterey Fm. (siliceous shale/mudstone)
Tw (PA) Whiskey Hill Formation Arkosic, glauconitic sandstones and tuffaceous siltstone	R = -- N = 0 N ≥ 4.0 pCi/L = 0 Maximum = -- pCi/L	Moderate (P) Based in Rn data from San Mateo County (Churchill, 2014)
	N=405	

Table 8. Moderate Radon Potential Geologic Units in Santa Clara County Based on 2015-2016 CDPH Short-term Indoor-radon Data. (P), R*, (PA), and (SJ) see Table 7 footnotes.

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
fg (PA) Franciscan Complex-greenstone	R = 0%? N = 7 N ≥ 4.0 pCi/L = 0 Maximum = 3.2 pCi/L	Low (P) Franciscan Complex geologic units typically low radon potential
fm (PA) Franciscan Complex-metamorphic rocks; and (SJ) Melange of the Central belt	R = 0%? N = 4 N ≥ 4.0 pCi/L = 1 Maximum = 4.4 pCi/L	Low (P) Franciscan Complex geologic units typically low radon potential
fms (SJ) Graywacke-Marin Headlands terrane	R = 0%? N = 2 N ≥ 4.0 pCi/L = 0 Maximum = 3.7 pCi/L	Low (P) Franciscan Complex geologic units typically low radon potential
fms ls (SJ) Landslide in graywacke-Marin Headlands terrane	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 3.4 pCi/L	Low (P) Franciscan Complex geologic units typically low radon potential
Jsp (SJ) Serpentinite	R = 0%? N = 2 N ≥ 4.0 pCi/L = 0 Maximum = 3.4 pCi/L	Low (P) Serpentinite typically low radon potential
Qa (SJ) Quaternary alluvium undivided	R = 0%? N = 2 N ≥ 4.0 pCi/L = 0 Maximum = 2.1 pCi/L	Low (P) Small deposits in southwestern map area in watersheds with few or no radon source rocks
Qhaf (PA) Holocene alluvial fan and fluvial deposits	R = 0%? N = 5 N ≥ 4.0 pCi/L = 0 Maximum = 3.4 pCi/L	Low (P) Small deposits in low Rn potential areas, sometimes separated from higher potential fans by creeks at fan boundaries
Qhb (PA and SJ) Holocene basin deposits	R = 2.2% N = 46 N ≥ 4.0 pCi/L = 1 Maximum = 7.1 pCi/L	Low (R* < 4.9%) Distal and downslope from low Rn potential fans
Qhf1 (SJ) Holocene alluvial fan deposits-younger	R = 0%? N = 8 N ≥ 4.0 pCi/L = 0 Maximum = 3.2 pCi/L	Low (P) Small fans, watersheds mostly low Rn potential but some with small Claremont Shale occurrences
Qhf2 (SJ) Alluvial fan deposits-older, principal Holocene fans and associated terraces	R = 0.0% N = 27 N ≥ 4.0 pCi/L = 0 Maximum = 3.8pCi/L	Low (R* < 4.9%) Few or no Rn source rocks in watersheds, east and southeast parts of map area
Qhfp (PA and SJ) Holocene flood plain deposits table continued on next page	R = 0.0 N = 25 N ≥ 4.0 pCi/L = 0 Maximum = 2.4 pCi/L	Low (R* < 4.9%) North part of map area, distal to moderate potential alluvial fans, sometimes separated from fans by creeks with natural levees

Qhl (PA and SJ) Holocene natural levee deposits	R = 0%? N = 19 N ≥ 4.0 pCi/L = 0 Maximum = 3.4 pCi/L	Low (P) Along Coyote Creek-watershed has low few Rn source rocks
Qht (SJ) Holocene stream terrace deposits, queried	R = 00%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 0.9 pCi/L	Low (P) Terraces in low Rn potential alluvial deposits along Coyote Cr.
Qpaf (PA) Pleistocene alluvial fan and fluvial deposits	R = 0.0% N = 40 N ≥ 4.0 pCi/L = 0 Maximum = 3.0 pCi/L	Low (R* < 4.9%) Some watersheds have small Monterey Fm occurrences but are mostly low Rn potential
Qpaf1 (PA) Pleistocene alluvial terrace deposits	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 1.7 pCi/L	Low (P) V. small deposit along Adobe Cr., mostly low Rn potential upstream
Qpf (SJ) Pleistocene alluvial fan deposits	R = 1.3% N = 77 N ≥ 4.0 pCi/L = 1 Maximum = 8.6 pCi/L	Low (R* < 4.9%) Some watersheds have small Monterey Fm occurrences but are mostly low Rn potential
Qpf ls (SJ) Landslide in upper Pleistocene alluvial fan deposits	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 0.9 pCi/L	Low (P) See Qpf comment
QTsc (PA and SJ) lower Pleistocene and upper Pliocene Santa Clara Formation	R = 0.0% N = 38 N ≥ 4.0 pCi/L = 0 Maximum = 2.8 pCi/L	Low (R* > 4.9%) Fluvial/lacustrine sediments typically low radon potential
Tus (SJ) middle to lower Miocene sandstone in upper part of Monterey Formation, New Almaden Block	R = 0%? N = 2 N ≥ 4.0 pCi/L = 0 Maximum = 1.7 pCi/L	Low (P) Quartzofeldspathic sandstone, likely low radon potential
	N=308	

Table 9. Low Radon Potential Geologic Units in Santa Clara County Based on 2015-2016 CDPH Short-term Indoor-radon Data (P), R*, (PA), and (SJ) see Table 7 footnotes.

The alluvial units assigned to preliminary moderate radon potential status also have preliminary low radon potential status occurrences (compare Tables 8 and 9).
While the geologic unit radon status is defined as a percentage of ≥ 4.0 pCi/L data, the radon populations of the moderate and low potential areas of some of these units are not all statistically different at a 95 percent confidence level (using the Mann-Whitney rank sum test). Those moderate and low potential units with statistically different radon populations are Qhl, Qhfp, and Qpaf. Those moderate and low potential units with radon populations not statistically different are Qhb, Qhf2 and Qpf. A “not statistically different” result on this statistical test means that that there is no compelling reason to reject the null hypothesis that the difference between the two populations is due to

random sampling. It is not the same as saying that the two populations are the same. A “statistically different” result means there is a less than 5 percent chance that the difference between the two populations is due to random sampling. The preliminary moderate and low radon potentials for Qhb, Qhf2, and Qpf may be modified based on review of airborne radiometric data and soil data in Appendix H. If not, their radon data and areas will be combined with other geologic unit populations to create the final moderate and low radon potential zones, provided the final combined radon populations for these zones are statistically different at the 95 percent confidence level.

Bedrock Geologic Units—Preliminary Radon Potentials

The Monterey Formation (Tm/Tms) consists of porcelaneous shale with chert, porcelaneous mudstone, impure diatomite, calcareous claystone with small amounts of siltstone and sandstone near its base (Brabb and others, 2000). The Monterey Formation has been previously documented in CGS radon studies as having higher potential for indoor-radon concentrations exceeding 4.0 pCi/L in California coastal counties from Los Angeles to San Mateo (Churchill, 2014; 2012; 2010; 2008; 2007; 2006; and 2005). The 29 indoor-radon data for homes located within Monterey Formation areas in Santa Clara County (Table 7) support a high radon potential designation.

The San Lorenzo Formation (Tsl) and the Rices Mudstone Member (Tsr) of the San Lorenzo Formation have lithologic and chemical characteristics in common with the Monterey Formation. They have been previously assigned as having higher radon potentials in San Mateo and Santa Cruz Counties (Churchill, 2014; and 2010). For the San Lorenzo Formation (undivided), three of four home measurements exceeded 4.0 pCi/l with a maximum concentration of 24.5 pCi/L. For Rices Mudstone Member-San Lorenzo Formation (in a landslide area) one of two home measurements exceed 4.0 pCi/L (9.8 pCi/L). Based on the available indoor-radon data, the previous high potential assignments for these units in San Mateo (Churchill, 2014) and Santa Cruz (Churchill, 2010) counties, and the lithologic and chemical similarities with the Monterey Formation, these units are assigned to preliminary high radon potential status for Santa Clara County.

The Claremont Formation (Tcc) in the San Jose quadrangle consists of massive to laminated chert, finely laminated siliceous shale with up to 1-meter-long interbedded lenses of dolomite and locally present quartz sandstone and siltstone (Wentworth, 1999). It has been assigned a preliminary moderate radon potential classification (provisional) because of its similarity to the Monterey Formation and having an associated indoor-radon measurement above 4.0 pCi/L.

The Ladera Sandstone (Tlad) in the Palo Alto quadrangle consists of poorly cemented sandstone and siltstone (90 percent), with minor coarse-grained sandstone, dolomitic claystone and porcelaneous shale and porcelanite (Brabb and others, 2000). It has been assigned a preliminary moderate radon potential classification (provisional) because of its similarity to the Monterey Formation (i.e., containing porcelaneous shale and porcelanite) and having an associated indoor-radon data above 4.0 pCi/L.

The unnamed marine sandstone and shale unit (upper Miocene) Tms) in the Palo Alto quadrangle (Tms-PA in Table 8) consists of soft, friable, very fine to medium-grained, well-sorted, poorly cemented quartzose sandstone with minor interbeds of siliceous mudstone and semi-siliceous shale (Brabb and others, 2000). It has been assigned a preliminary moderate radon potential classification based on its similarity to the Monterey Formation (i.e., containing siliceous shale and mudstone) and having an associated indoor-radon measurement of 16.2 pCi/L.

Monterey Shale Sandstone (Tus) in the San Jose quadrangle consists of quartzofeldspathic sandstone or lithic arkose in the upper part of the Monterey Shale Formation. It has been assigned a preliminary low radon potential classification (provisional) because sandstone units in California often have low radon potential and the highest of two associated indoor-radon measurements is 1.7 pCi/L.

Other Information Available for Geologic Unit Radon Potential Evaluation

Rock and soil uranium background concentration data can suggest where radon potential is relatively high and where it is relatively low. NURE program airborne radiometric data for uranium have been often used for this purpose in radon potential mapping (see U.S. EPA, 1993, and previous CGS radon potential mapping reports). Such information is particularly useful in areas where indoor-radon data are sparse or absent.

Like uranium background information, certain soil properties are commonly used during radon potential mapping projects to suggest where radon potentials might be higher or lower. Properties most commonly scrutinized are permeability (hydraulic conductivity), shrink-swell (linear extensibility), hydraulic soil group, depth to bedrock or an impermeable horizon, and depth to water table. These property categories relate to radon migration in the subsurface. Soil permeability information is used to gauge the ease of radon migration in the subsurface even though it is for water permeability and not soil gas permeability. This is largely because water permeability information is readily available in NRCS soil reports while soil gas permeability information is rarely available.

Both NURE airborne uranium data and NRCS soil data were compiled and reviewed to see if they support the provisional high, moderate, and low radon potentials for geologic units based on indoor-radon data. They were also reviewed to see if they suggest additional areas in Santa Clara County with elevated radon potentials where indoor-radon data are sparse or unavailable. Unfortunately, uncertainty regarding the accuracy of some of the NURE airborne radiometric data and urban development disturbance of soils at most indoor-radon data locations prevented the use of these data in evaluating individual geologic unit radon potentials. Detailed information about the Santa Clara

County NURE airborne radiometric data, NRCS soil data, and evaluation of these data is available in Appendix H.

RADON POTENTIAL ZONES

Final Santa Clara County Geologic Unit Radon Potentials

Santa Clara County radon potential zones are based on the locations of geologic units classified as having high, moderate, low, or unknown radon potential. The final rankings of the Santa Clara County geologic units for this report and the associated radon potential map are based upon: 1) indoor-radon data; 2) geologic unit radon potential information from previous CGS radon studies, especially those for San Mateo and Santa Cruz counties (Churchill, 2014 and 2010). Uncertainty regarding the accuracy of some of the NURE airborne radiometric data and urban development disturbance of soils at most indoor-radon data locations prevented the use of these data in evaluating the radon potentials of individual geologic units. Statistical comparisons of eU populations within the San Francisco, San Jose, and Monterey quadrangles do support the moderate potential zone and unknown potential zone being statistically distinct from the other radon potential zones. High potential and low potential area eU populations were not statistically distinct but that outcome may result from the small sizes of these populations. The radon data and eU data populations for areas with manufactured layer horizon (MLH) soils (urban development) are statistically different from those populations with non-MLH soil areas. MLH soils appear to be slightly higher in radon potential than non-MLH soils. However, the differences are not great enough to warrant changes in preliminary radon potential zone boundaries.

Final Santa Clara County Radon Potential Zones

Figure 3 shows the Santa Clara County radon potential zones and Figure 4 shows the radon zones in relationship to CDPH Indoor Radon Program survey data. Tables 10 and 11 contain information about the radon data population characteristics for each radon potential zone. Tables 12 and 13 provide information about ≥ 4.0 pCi/L indoor concentration incidence rates for each radon potential zone and the density of indoor-radon survey data per zone. Table 12 shows that the high radon potential zone only accounts for 1.99 percent of the Santa Clara radon potential map area but contains 29.3 percent of ≥ 4.0 pCi/L CDPH survey locations. It also shows the combined high and moderate radon potential areas represent 15.70 percent of the map area but contain 90.3 percent of ≥ 4.0 pCi/L CDPH survey locations. Table 13 shows that the Santa Clara radon potential map area averages about one home indoor-radon measurement per 1.06 square miles.

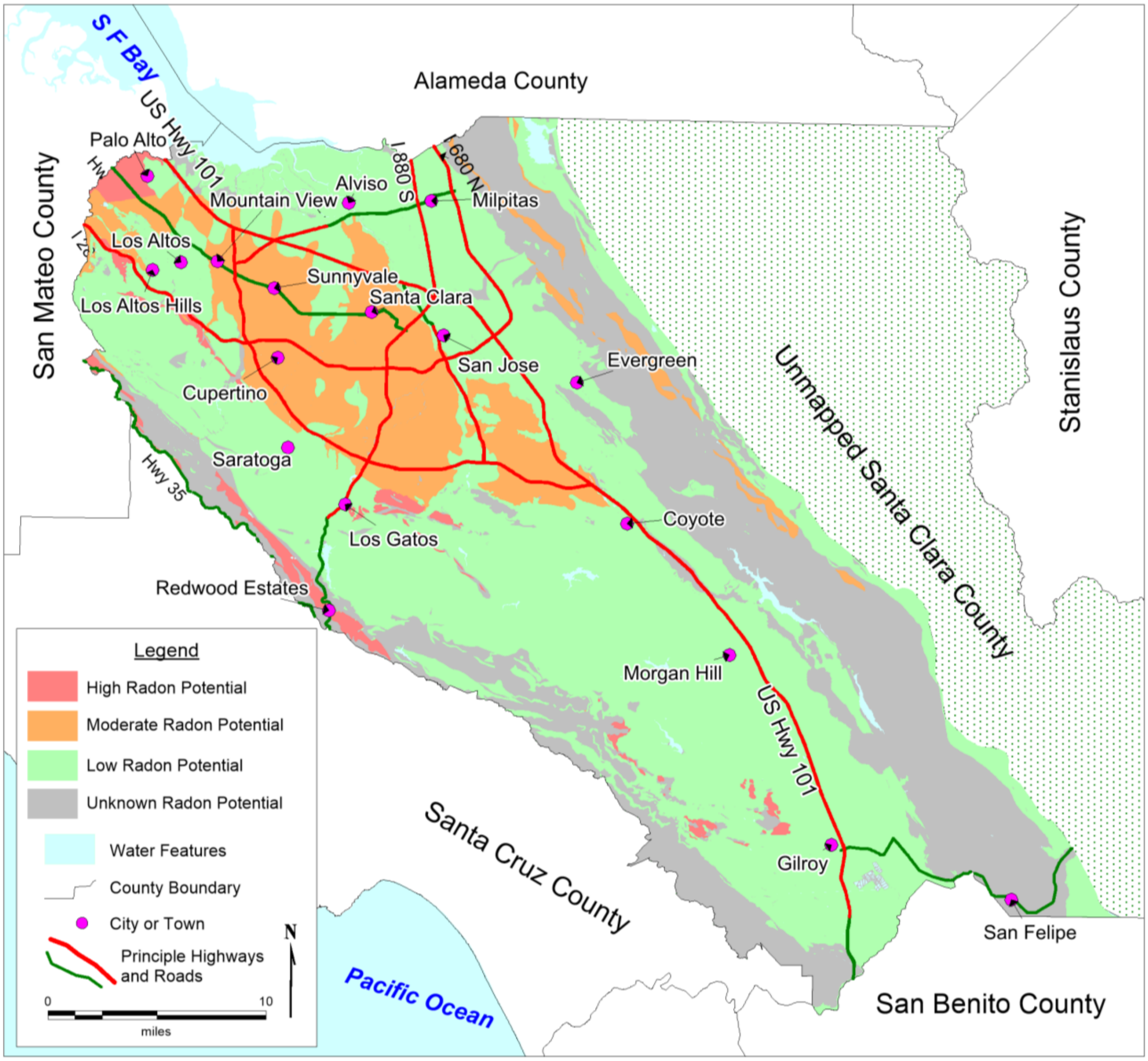
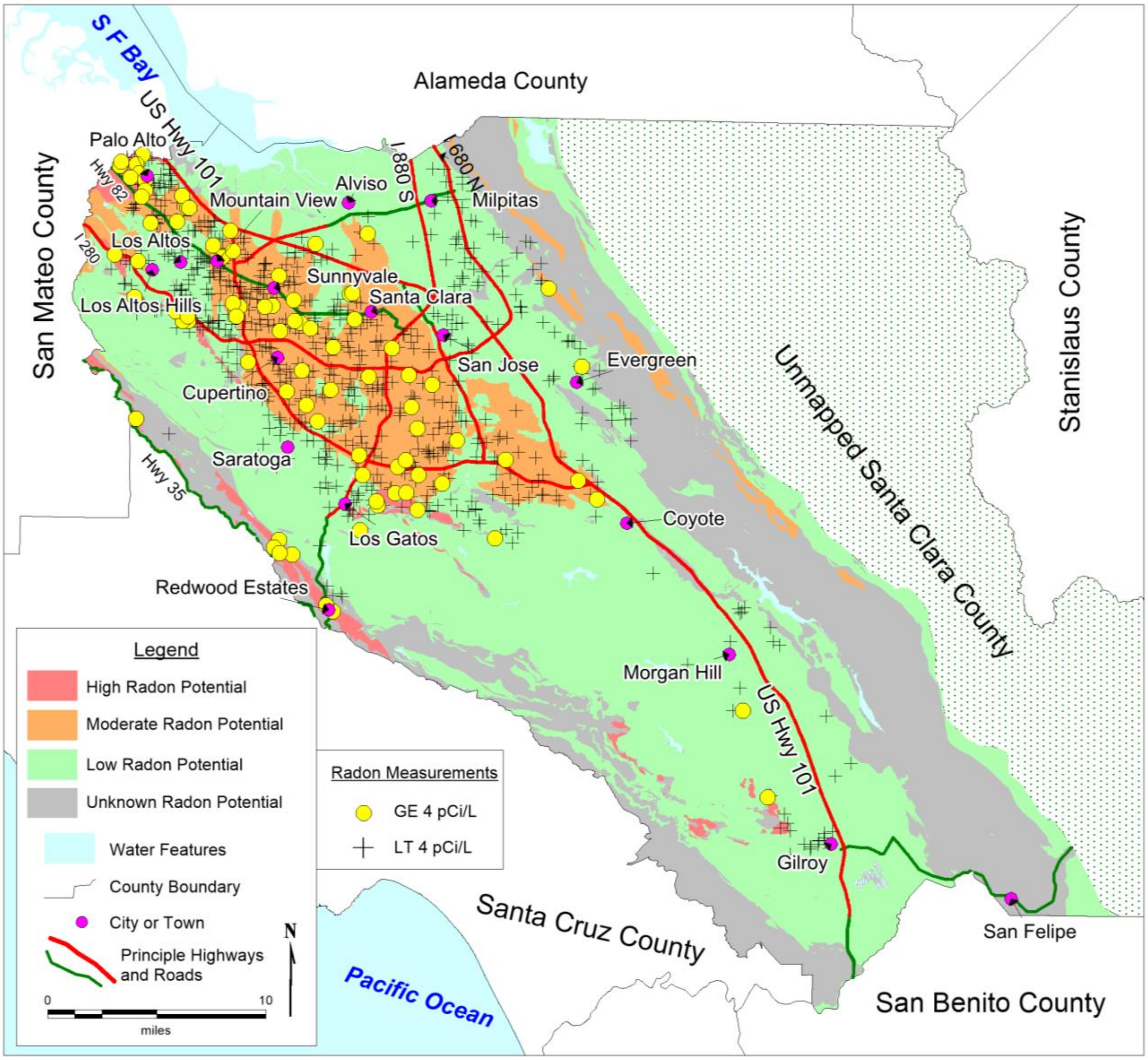


Figure 3. Santa Clara County Radon Potential Zones



Note: GE = greater than or equal to and LT = less than

Figure 4. Santa Clara County Radon Potential Zones Showing Supporting Radon Data at or Above 4.0 pCi/L and Below 4.0 pCi/L

Potential Zone	n	Median pCi/L	pCi/L at 25%	pCi/L at 75%	Minimum pCi/L	Maximum pCi/L
High	60	2.8	1.625	5.35	0.8	24.5
Moderate	405	1.7	1.2	2.6	0.4	39.6
Low	308	1.4	1.0	2.0	0.4	8.6
Unknown	20	1.35	0.825	4.725	0.4	24.5
All	793	1.6	1.1	2.4	0.4	39.6

Table 10. Radon Zone Data Characteristics for Santa Clara County

Potential Zone	n	n ≥ 4.0 pCi/L	% data ≥ 4.0 pCi/L	n ≥ 10.0 pCi/L	% data ≥ 10.0 pCi/L	n ≥ 20.0 pCi/L	% data ≥ 20.0 pCi/L	Area-land only (sq.-mi)
High	60	24	40.0	5	8.3	1	1.7	16.7
Moderate	405	50	12.4	6	1.5	1	0.25	115.2
Low	308	3	0.97	0	0.0	0	0.0	474.0
Unknown	20	5	25.0	2	10.0	1	5.0	234.2
All	793	82	10.3	13	1.64	3	0.38	840.1

Table 11. n ≥ 4.0 pCi/L Incidence Per Radon Zone in Santa Clara County

Zone	% of all n ≥ 4.0 pCi/L data	% of all n ≥ 10.0 pCi/L data	% of all n ≥ 20.0 pCi/L data	% Mapped Area	Cumulative % of all ≥ 4.0 pCi/L data	Cumulative % of Santa Clara County Area
High	29.3	38.5	33.3	1.99	29.3	1.99
Moderate	61.0	46.2	33.3	13.71	90.3	15.70
Low	3.7	0.0	0.0	56.42	94.0	72.12
Unknown	6.1	15.4	33.3	27.88	100.1	100.00
All	100.1	100.1	100.0	100.00		

Table 12. ≥ 1.0 Incidence Rates for Santa Clara County by Radon Potential Zone

Zone	Average Rate: n ≥ 4.0 pCi/L Measurements per square mile*	Average Rate: Total measurements per square mile*
High	1.44	3.59
Moderate	0.434	3.52
Low	0.0063	0.650
Unknown	0.0213	0.0854
All	0.0976	0.9439

*****Within radon map area, not whole county area.

Table 13. Radon Data Distribution by Radon Potential Zone

RADON POTENTIAL ZONE STATISTICS

Indoor-Radon Data Characteristics

Indoor-radon survey data population descriptive statistics for each final radon potential zone for untransformed and log-transformed data (i.e., data converted to natural logarithm values) are provided in Appendix V and Appendix W and are briefly discussed below.

Indoor-Radon Data Frequency Distributions

A lognormal frequency distribution is often the assumed statistical distribution for rock and soil trace element data, e.g., uranium and radon (Nero and others, 1986). However, because of the variety of geologic units and complex history of processes affecting them, geochemical data cannot always be fit to a specific frequency distribution (Rose and others, 1979, p. 33). Untransformed and log-transformed radon data for the final radon potential zones, and for the Santa Clara radon map area overall, were tested for normality using the Shapiro-Wilk normality test. Appendix X contains the test results. The untransformed data populations all failed the normality test and vary significantly from the pattern expected if they were drawn from a normally distributed population. Log-transformed high zone, low zone, and unknown zone data populations passed the normality test while moderate zone and the "all data" populations failed the normality test. Data populations neither normally nor lognormally distributed may be a combination of samples from several different normal and/or lognormal populations. Each rock unit has its own unique radon population distribution. On an individual basis, the rock unit populations may be lognormal or normal, but the aggregate of several unit populations may not be either normal or lognormal in distribution.

Data non-normality has important implications for certain statistical operations. For example, t-test comparisons should not be used for comparing non-normal populations. For this reason, the Mann-Whitney rank sum test is used for comparisons of sub-populations of indoor-radon test data by radon zone in this study. Non-normality may have negative consequences for predictions of percentages of homes with indoor-radon levels exceeding 4.0 pCi/L, where such predictions incorrectly assume a lognormal population distribution for a radon data population.

Statistical Comparison of Indoor-Radon Data by Radon Potential Zone

Mann-Whitney rank sum test statistical comparisons of high, moderate, and low potential zone indoor-radon data populations are listed in Appendix Y. Results of these comparisons show the indoor-radon data population for each of these radon zones is statistically distinct with P=0.001 or less (a 1/1000 chance or less that the populations are not distinct). These results, along with the medians for each data population decreasing in rank order (high potential median > moderate potential median > low potential median), are evidence supporting the validity of Santa Clara County radon potential zone definitions.

Comparisons of these zones with the unknown potential zone data population shows it is statistically distinct (overall the unknown potential data are lower in radon concentration) from the high radon potential data but not statistically different from the moderate and low potential radon data populations. Such data overlap is to be expected because the unknown potential zone is likely composed of some data from all the other zones potential categories. Additional indoor-radon data are needed to identify which portions of the unknown potential zone should be assigned to high, moderate, or low potential categories.

Estimated Santa Clara County Population Exposed to 4.0 pCi/L or Higher Radon Concentrations in Indoor Air

Santa Clara radon potential map population estimates for each radon potential zone were obtained using GIS methods to overlay Santa Clara radon potential zones with 2010 census tract data (U.S. Department of Commerce, 2015). For a census tract not completely within a radon potential zone, the population contribution from that tract was considered equal to the percentage area of the tract within the radon zone. Table 14 lists the resulting population estimates and the estimated number of homes for different radon potential zones.

Radon Potential Zone	Estimated Total Population within Zone—2010 Census Statistics	Estimated Total Homes within Zone—2010 Census Statistics	
		Average Household Population*	Estimated Number of Homes
High	33,962	2.95	11,513
Moderate	757,241	2.95	256,692
Low	905,158	2.95	306,833
Unknown	84,410	2.95	28,614
Total	1,780,771	2.95	603,652

Table 14. Population and Home Estimates for Radon Potential Zones

*Persons per household, 2011-2015, Santa Clara County Quick Facts from the U.S. Census Bureau https://www.census.gov/quickfacts/table/PST045216/06085,0669084

Table 15 contains population estimates for each radon potential zone and estimates for individuals exposed to ≥ 4.0 pCi/L, ≥ 10.0 pCi/L and ≥ 20.0 pCi/L indoor-radon concentrations in each potential zone. Table 15 also contains estimates for individuals exposed to ≥ 4.0 pCi/L based upon:

- the radon zone ≥ 4.0 pCi/L percentages and populations (weighted)
- the overall CDPH Indoor Radon Program Santa Clara County radon survey ≥ 4.0 pCi/L percentage and county population (unweighted)
- the CDPH Zip Code data ≥ 4.0 pCi/L percentage for Santa Clara County and county population (unweighted).

Santa Clara County Population Estimates by Radon Zone (does not include population within the unmapped portion of the county)						
Radon Potential Zone	**Estimated Total Population for Zone**	**Estimated Population at ≥ 4.0 pCi/L Conditions**	**Estimated Population at ≥ 10.0 pCi/L Conditions**	**Estimated Population at ≥ 20.0 pCi/L Conditions**	**Percent Area**	**Square Miles**
High	33,962	13,585	2,819	577	1.99	16.7
Moderate	757,241	93,898	11,359	1,893	13.71	115.2
Low	905,158	8,780	0.0	0.0	56.42	474.0
Unknown	84,410	21,103	8,441	4,221	27.88	234.2
Population Estimate Weighted by Radon Zone and Population Distribution (i.e., the sum of each zone's population estimates)						
Totals	1,780,771	137,366 (7.7%)	22,619 (1.27%)	6,691 (0.376%)	100.00	840.1
Population Estimates by Radon Survey Results Without Regard to Radon Zone or Population Distribution (i.e., ≥ 4.0 pCi/L rate, ≥ 10.0 pCi/L rate, and ≥ 20.0 pCi/L rate multiplied by total population)						
Totals for Santa Clara County	1,780,771	183,419* (10.3%) 170,954** (9.6%)	29,205* (1.64%)	6,767* (0.380%)	100	840.1

Table 15. Estimates of Santa Clara County Radon Map Area Population Exposed to 4.0 pCi/L or Greater Indoor-radon Levels in Residences (using 2010 U.S. Census data)

*Estimated using 2015-2016 CDPH indoor-radon survey data (see Table 11, row "All")

**Estimated using CDPH Zip Code data (February 2016 version) for Santa Clara County (See Table 4, last row)

SANTA CLARA COUNTY RADON MAPPING PROJECT SUMMARY

Procedures and Results

Short-term radon test data from the CDPH Indoor Radon Program, NURE program airborne radiometric data, and NRCS soil data were reviewed to evaluate geologic units in Santa Clara County for their potential to be associated with homes at or above the U.S. EPA recommended radon action level of 4.0 pCi/L. Geologic units were classified as having high, moderate, low, or unknown radon potential based on the percentage of 4.0 pCi/L or higher indoor-radon test results. Radon potential mapping was completed for 65.1 percent of Santa Clara County (the western portion, 840.1 square miles). The eastern portion of the county was not mapped because no indoor-radon data were available (it is sparsely populated) and there are uncertainties regarding NURE airborne eU data accuracy within this portion of the county. Individuals in the eastern portion of Santa Clara County concerned about radon should test their homes.

The final radon potential zones have the following characteristics:

<u>High Radon Potential Zone</u>: comprises 1.3 percent (16.7 square miles) of Santa Clara County and contains 29.3 percent of the ≥ 4.0 pCi/L data and 33.3 percent of the ≥ 20 pCi/L data in the Santa Clara County CDPH Indoor Radon Program survey. The maximum indoor-radon survey measurement for a home in this zone is 24.5 pCi/L (for a first-floor master bedroom).

<u>Moderate Radon Potential Zone</u>: comprises 8.9 percent (115.2 square miles) of Santa Clara County and contains 61.0 percent of the ≥ 4.0 pCi/L data and 33.3 percent of the ≥ 20 pCi/L data in the Santa Clara County CDPH Indoor Radon Program survey. The maximum CDPH indoor-radon survey measurement for a home in this zone is 39.6 pCi/L for a basement room.

<u>Low Radon Potential Zone</u>: comprises 36.7 percent (474.0 square miles) of Santa Clara County and contains 3.7 percent of the ≥ 4.0 pCi/L data and no ≥ 10 pCi/L data in the Santa Clara County CDPH Indoor Radon Program survey. The maximum CDPH indoor-radon survey measurement for a home in this zone is 8.6 pCi/L for a first-floor unspecified room.

<u>Unknown Radon Potential Zone</u>: comprises 18.2 percent (234.2 square miles) of Santa Clara County and contains 6.1 percent of the ≥ 4.0 pCi/L data and 33.3 percent of the ≥ 20 pCi/L data in the Santa Clara County CDPH Indoor Radon Program survey. The maximum CDPH radon survey measurement for a home in this zone is 24.5 pCi/L for a basement wine cellar.

Note that indoor-radon concentrations exceeding the U.S. EPA recommended action level of 4.0 pCi/L and indoor-radon concentrations below this action level were identified in every radon potential zone. The only way to know the indoor-radon concentration in a home or building is by testing the indoor-air for radon, regardless of the zone in which the building is located.

Statistical comparison of the indoor-radon data populations for the high, moderate, and low radon potential zones, using the Mann-Whitney rank sum test, shows the zones differ from each other statistically. Note the P values for these tests (the probability of being wrong in concluding that there is a true difference between the groups) listed in Appendix Y are equal or less than 0.001. This is strong statistical support for the different Santa Clara County radon potential zones representing distinct groups of indoor-radon potentials.

RECOMMENDATIONS

Indoor-radon testing should be encouraged in Santa Clara County, particularly in the high and moderate radon potential zone areas which represent about 10 percent of the total county area. Additional indoor-radon measurements within unknown potential areas should also be encouraged because there are insufficient data currently available in these areas to estimate their radon potential.

Those considering new home construction, particularly at sites within high and moderate radon potential areas, may wish to consider radon resistant new construction practices. Post construction radon mitigation is possible, if necessary, but will be more expensive than the cost of adding radon reducing features during house construction.

In recent years, some south Bay Area homes have been remodeled to add basements. Homes with basements in Santa Clara County have an increased incidence of indoor-radon concentrations exceeding the U.S. EPA action level of 4.0 pCi/L. Indoor-radon testing should be encouraged in homes that have added basements and radon-resistant new construction practices should be considered for basement additions to homes.

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APPENDIX A
Concurrent Indoor-Radon Test Data

(Multiple short-term radon tests in a residence conducted during the same time; test results for two or more shaded adjacent rows are from the same house; high measurement floor and room listed first)

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*	Test Dates	City or Area	Test Floor and Room
39.6	6.6	33.0	83.3	01/11-14/2015	San Jose	Basement, room? and 1st floor family room
19.0	17.7	1.3	6.8	09/28-10/01/15	Mtn. View	Basement under living room and 1st floor master bedroom
19.0	6.1	12.9	67.9	09/28-10/01/15	Mtn. View	Basement under living room and 1st floor garage
17.7	6.1	11.6	65.5	09/28-10/01/15	Mtn. View	1st floor master bedroom and 1st floor garage
16.2	2.7	13.5	83.3	04/13-16/14	Los Altos	Basement bedroom and basement room?
15.1	2.3	12.8	84.8	05/23-26/16	Palo Alto	Basement, under stairs, and basement play room
15.1	2.3	12.8	84.8	05/23-26/16	Palo Alto	Basement, under stairs, and basement storage room
15.1	2.0	13.1	86.8	05/23-26/16	Palo Alto	Basement, under stairs, and basement laundry room
2.3	2.3	0.0	0.0	05/23-26/16	Palo Alto	Basement play room and basement storage room
2.3	2.0	0.3	13.0	05/23-26/16	Palo Alto	Basement play room and basement laundry room
2.3	2.0	0.3	13.0	05/23-26/16	Palo Alto	Basement storage room and basement laundry room
12.3	5.2	7.1	57.7	12/26-29/16	Sunnyvale	Both in basement
8.7	7.1	1.6	18.4	01/14-17/16	Gilroy	2nd floor office
6.2	4.8	1.4	22.6	01/09-12/16	Sunnyvale	1st floor, rooms?
6.1	1.6	4.5	73.8	03/27-29/13	Palo Alto	Basement living room and 1st floor kitchen
6.1	1.3	4.8	78.7	03/27-29/13	Palo Alto	Basement living room and 1st floor living room
1.6	1.3	0.3	18.8	03/27-29/13	Palo Alto	1st floor kitchen and living room
5.9	2.0	3.9	66.1	12/05-07/12	Palo Alto	Basement green room and 1st floor dining/living room

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*	Test Dates	City or Area	Test Floor and Room
5.6	5.1	0.5	8.9	04/12-14/16	Palo Alto	Both in basement
4.7	4.1	0.6	12.8	01/22-24/16	Mtn. View	1st floor garage
4.6	4.1	0.5	10.9	01/09-12/16	Palo Alto	Floor and room? and 1st floor living room
4.5	4.2	0.3	6.7	02/19-02-21	Los Gatos	Basement and basement bedside
4.5	4.1	0.4	8.9	02/19-02-21	Los Gatos	Both in basement
4.4	4.4	0.0	0.0	12/28-31/15	San Jose	1st floor bedroom
4.2	2.9	1.2	28.6	12/30/15-01/02/16	San Jose	Floor and room? and 1st floor “center”?
4.1	3.2	0.9	22.0	01/07-09/16	Los Gatos	1st floor, “lower floor” bedroom
4.1	2.8	1.3	31.7	12/31/15-01/03/16	Santa Clara	1st floor bedroom and 1st floor, room?
3.8	3.4	0.4	10.5	01/27-31/16	San Jose	1st floor hall
3.7	3.4	0.3	8.1	01/18-20/16	Los Gatos	1st floor family room
3.7	3.1	0.6	16.2	01/21-24/2016	Los Gatos	Basement, rooms?
3.6	3.1	0.5	13.9	01/24-27/16	Los Altos	1st floor bedroom
3.5	3.2	0.3	8.6	03/01-03/16	Los Gatos	Floor(s)? and room(s)?
3.5	3.0	0.5	14.3	12/28-31/15	Los Gatos	1st floor laundry room
3.4	3.2	0.2	5.9	05/21-24/16	Los Altos	1st floor living room
3.4	2.4	1.0	29.4	01/26-30/16	San Jose	1st floor bedroom and floor? room?
3.2	2.9	0.3	9.4	01/30-02/01/16	Los Gatos	Both in basement
3.2	2.5	0.7	21.9	01/30-02/01/16	Los Gatos	Both in basement
3.2	2.5	0.7	21.9	02/15-18/16	Los Gatos	1st floor “living center area” and “center house living”
3.2	1.5	1.7	53.1	12/28-31/15	Campbell	1st floor, room(s)?
3.1	2.3	0.8	25.8	05/15-18/2016	Mtn. View	1st floor bathroom and 1st floor master bedroom
3.1	1.5	1.6	51.6	05/15-18/2016	Mtn. View	1st floor bathroom and 1st floor bedroom
3.1	1.4	1.7	54.8	05/15-18/2016	Mtn. View	1st floor bathroom and 1st floor kitchen
2.3	1.5	0.8	34.8	05/15-18/2016	Mtn. View	1st floor master bedroom and 1st floor bedroom
2.3	1.4	0.9	39.1	05/15-18/2016	Mtn. View	1st floor master bedroom and 1st floor kitchen
1.5	1.4	0.1	6.7	05/15-18/2016	Mtn. View	1st floor bedroom and 1st floor kitchen

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*	Test Dates	City or Area	Test Floor and Room
3.0	2.5	0.5	16.7	01/26-28/16	Santa Clara	1st floor kitchen
2.9	2.4	0.5	17.2	12/29/15-01/01/16	San Jose	1st floor, rooms?
2.7	1.1	1.6	59.3	10/10-04/16	Gilroy	1st floor kitchen
2.6	2.1	0.5	19.2	12/27-29/15	San Jose	1st floor family room
2.5	2.5	0.0	0.0	12/29/15-01/02/16	Saratoga	1st floor dining room
2.5	2.2	0.3	12.0	12/29/15-01/01/16	San Jose	1st floor living room
2.5	2.0	0.5	20.0	01/17-21/16	San Jose	1st floor, room(s)?
2.5	1.8	0.7	28.0	12/31/15-01/02/16	Los Altos	1st floor living room
2.4	2.1	0.3	12.5	01/18-20/16	San Jose	1st floor, side bedroom and front room
2.4	1.5	0.9	37.5	01/18-20/16	San Jose	1st floor family room
2.3	2.3	0.0	0.0	04/19-22/16	Los Gatos	2nd floor living room and 1st floor crawl space
2.3	2.1	0.2	8.7	04/19-22/16	Los Gatos	2nd floor living room and 3rd floor bedroom
2.3	1.9	0.4	17.4	04/19-22/16	Los Gatos	2nd floor living room and 3rd floor bedroom
2.1	1.9	0.2	9.5	04/19-22/16	Los Gatos	3rd floor bedroom
2.3	1.7	0.6	26.1	12/31/15-01/02/16	Sunnyvale	1st floor living room
2.2	2.0	0.2	9.1	01/25-28/16	San Jose	1st floor guest bedroom
2.1	1.9	0.2	9.5	02/05-09/16	Palo Alto	1st floor bedroom
2.1	1.9	0.2	9.5	01/18-21/16	Los Altos	1st floor bedroom
2.1	1.8	0.3	14.3	01/09-11/16	Los Altos	1st floor kitchen
2.1	1.6	0.5	23.8	03/06-09/16	Saratoga	1st floor living room
2.1	1.5	0.6	28.6	10/05-07/15	Campbell	1st floor, rooms?
2.0	1.7	0.3	15.0	12/28-31/15	San Jose	1st floor, room(s)?
2.0	1.2	0.7	35.0	01/03-05/16	Los Altos	1st floor bedroom and spare bedroom
1.9	1.2	0.7	36.8	12/28-31/15	Campbell	1st floor living room
1.8	1.8	0.0	0.0	01/13-16/2016	Sunnyvale	1st floor, room(s)?
1.8	1.4	0.4	22.2	12/28/15-01/01/16	Los Gatos	1st floor, room(s)?
1.7	1.6	0.1	5.9	01/19-23/16	San Jose	1st floor, room? and 1st floor, “closet shelf 6.5 feet off floor”-room?
1.7	1.5	0.2	11.8	11/10-13/12	Gilroy	1st floor master bedroom
1.7	1.3	0.4	23.5	11/10-13/12	Gilroy	1st floor master bedroom and kitchen

High (pCi/L)	Low (pCi/L)	Difference (pCi/L)	Percent Difference*	Test Dates	City or Area	Test Floor and Room
1.7	1.2	0.5	29.4	10/02-05-15	Palo Alto	Basement-unfinished and 1st floor bedroom
1.6	1.4	0.2	12.5	12/28-30/15	Gilroy	1st floor, "closet shelf" room(s)?
1.6	1.3	0.3	18.8	01/05-07/16	Mtn. View	1st floor bedroom
1.6	1.3	0.3	18.8	08/03-06/12	Sunnyvale	1st floor kitchen
1.6	1.3	0.3	18.8	02/07-10/16	San Jose	1st floor dining room
1.5	1.2	0.3	20.0	01/16-19/2016	San Jose	1st floor bedroom
1.4	0.9	0.5	35.7	05/20-22/16	Cupertino	1st floor master bedroom
1.4	0.8	0.6	42.9	01/04-07/16	Los Gatos	1st floor living room
1.3	1.2	0.1	7.7	01/07-10/16	San Jose	1st floor, room(s)?
1.3	1.1	0.2	15.4	03/21-24/16	Mtn. View	1st floor play room
1.3	0.8	0.5	38.5	01/08-11-16	Palo Alto	1st floor bedroom and unspecified
1.2	1.0	0.2	16.7	01/20-22/16	Campbell	1st floor bedroom
1.2	1.0	0.2	16.7	01/22/16-01/25/16	Sunnyvale	1st floor living room and 1st floor family room
1.2	0.8	0.4	33.3	01/29-02/01/2016	San Jose	1st floor living room and floor? room?
1.2	0.7	0.5	41.7	12/27-31/15	Palo Alto	1st floor bedroom
1.1	1.0	0.1	9.1	05/05-08/16	Los Gatos	1st floor dining room
1.1	1.0	0.1	9.1	01/20-23/16	Sunnyvale	1st floor living room "near center, and 1st floor living room
1.0	1.0	0.0	0.00	02/19-21/16	San Jose	1st floor living room
1.0	0.7	0.3	30.0	01/14-17/16	Santa Clara	1st floor second bedroom
0.9	0.7	0.2	22.2	01/02-04/16	Milpitas	1st floor dining room
0.8	0.7	0.1	12.5	03/06-09/16	San Jose	1st floor kitchen
0.8	0.5	0.3	37.5	3/29-31/16	Cupertino	1st floor dining room

*Percent difference = ((high Rn-low Rn)/high Rn) X 100

APPENDIX B
Charcoal Detector Field Blanks

Data Analyzed	Results pCi/L					
01/06/2016	0.7	0.6	0.6	0.6	0.6	0.6	0.6
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.3	0.3					
02/04/2016	0.7	0.7	0.7	0.7	0.6	0.6	0.6
	0.6	0.6	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.3
	0.3	0.3					
02/23/2016	0.7	0.7	0.7	0.6	0.6	0.6	0.6
	0.6	0.6	0.6	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.4
	0.4	0.4	0.4	0.4	0.4	0.3	0.3
	0.3	0.3	0.2	0.2			
03/19/2016	0.6	0.6	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	0.3	0.3	0.3	0.2	0.3	0.2	0.2
	0.2	0.2					
04/14/2016	0.6	0.6	0.6	0.6	0.5	0.5	0.5
	0.5	0.5	0.5	0.3	0.5	0.5	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	0.3	0.2	0.2	0.2	0.2	0.1	
05/16/2016	0.6	0.6	0.6	0.6	0.6	0.6	0.4
	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	0.5	0.5	0.4	0.4	0.4	0.4	0.4
	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	0.3	0.3	0.3	0.3	0.3	0.3	

APPENDIX C

Laboratory Spikes of Charcoal Detectors

Dates exposed	Hours exposed	Mean Chamber Radon Conc. pCi/L	Test Result pCi/L	Difference from Mean Chamber Conc. pCi/L	Test Result within 10% of the Mean Chamber Radon Concentration
01/07/16 to 01/11/16	96	10.3	10.4	0.1	Yes
			9.5	-0.8	Yes
			9.1	-1.2	No
			9.9	-0.4	Yes
			9.9	-0.4	Yes
			9.1	-1.2	No
			11.1	0.8	Yes
			10.9	0.6	Yes
			9.9	-0.4	Yes
			10.9	0.6	Yes
			10.0	-0.3	Yes
			9.3	-1.0	No
			10.7	0.4	Yes
			10.4	0.1	Yes
			9.8	-0.5	Yes
			10.0	-0.3	Yes
			10.3	0.0	Yes
			10.3	0.0	Yes
02/05/16 to 02/08/16	72	13.2	12.7	-0.5	Yes
			12.4	-0.8	Yes
			12.7	-0.5	Yes
			11.7	-1.5	No
			11.6	-1.6	No
			12.9	-0.3	Yes
			11.8	-1.4	No
			12.3	-0.9	Yes
			12.9	-0.3	Yes
			11.1	-2.1	Yes
			11.7	-1.5	No
			13.0	-0.2	Yes
			12.6	-0.6	Yes
			13.1	-0.1	Yes
			11.9	-1.3	No
			12.6	-0.6	Yes
			12.2	-1.0	Yes
			13.1	-0.1	Yes
03/05/16 to 03/07/16	48	24.3	25.8	1.5	Yes
			24.2	-0.1	Yes
			24.6	0.3	Yes
			22.7	-1.6	Yes
			26.7	2.4	Yes
			23.3	-1.0	Yes
			24.4	0.1	Yes
next page			25.2	0.9	Yes

Dates exposed	Hours exposed	Mean Chamber Radon Conc. pCi/L	Test Result pCi/L	Difference from Mean Chamber Conc. pCi/L	Test Result within 10% of the Mean Chamber Radon Concentration
see previous page			24.6	0.3	Yes
			26.0	1.7	Yes
			25.4	1.1	Yes
			25.7	1.4	Yes
			23.6	-0.7	Yes
			21.2	-3.1	No
			25.6	1.3	Yes
			21.8	-2.5	No
			25.5	1.2	Yes
04/07/16 to 04/11/16	96	25.5	24.4	-1.1	Yes
			26.2	0.7	Yes
			25.7	0.2	Yes
			25.9	0.4	Yes
			25.5	0.0	Yes
			23.8	-1.7	Yes
			25.4	-0.1	Yes
			24.9	-0.6	Yes
			25.1	-0.4	Yes
			25.3	-0.2	Yes
			24.4	-1.1	Yes
			23.6	-1.9	Yes
			25.7	0.2	Yes
			28.1	2.6	Yes
			26.6	1.1	Yes
			25.8	0.3	Yes
			24.1	-1.4	Yes
			25.5	0.0	Yes
05/06/16 to 05/09/16	72	34.9	33.3	-1.6	Yes
			36.7	1.8	Yes
			37.0	2.1	Yes
			33.0	-1.9	Yes
			37.9	3.0	Yes
			36.4	1.5	Yes
			32.6	-2.3	Yes
			32.1	-2.8	Yes
			36.0	1.1	Yes
			37.9	3.0	Yes
			31.4	-3.5	No
			30.4	-4.5	No
			35.4	0.5	Yes
			34.4	-0.5	Yes
			37.7	2.8	Yes
			30.8	-4.1	No
			30.4	-4.5	No

APPENDIX D

Results of Follow-up Tests in Homes (tests on same floor)

Test 1 (pCi/L)	Test 2 (pCi/L)	Difference (pCi/L)	Percent Difference*	Days Between Tests	Date Test 1	Date Test 2
19.9	39.6	19.7	49.7	43	12/2/2014	1/14/2015
8.7	4.7	3.0	34.5	74	1/17/2016	3/31/2016
7.1	4.7	2.4	33.8	74	1/17/2016	3/31/2016
9.4	6.7	2.7	28.7	37	12/27/2015	2/2/2016
4.8	4.7	0.1	2.1	164	12/24/2012	6/6/2013
4.3	4.7	0.4	8.5	24	1/5/2016	1/29/2016
3.9	4.2	0.3	7.1	25	1/27/2016	2/21/2016
3.2	4.5	1.3	28.9	20	2/1/2016	2/21/2016
3.2	4.1	0.9	22.0	20	2/1/2016	2/21/2016
2.9	4.1	1.2	29.3	20	2/1/2016	2/21/2016
2.5	4.1	1.6	39.0	20	2/1/2016	2/21/2016
2.0	1.3	0.7	35.0	112	12/7/2012	3/29/2013

*Percent Difference = (Difference ÷ High) X 100

Test results for two or more shaded adjacent rows are from the same house.

APPENDIX E

Santa Clara County Geologic Units in the Radon Map Area and Radon Data

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
af	Artificial fill	Palo Alto	N
af	Artificial fill	San Jose	N
af alf	Artificial fill and artificial levee fill	Monterey	N
alf	Artificial levee fill	Palo Alto	N
cg	Conglomerate in mélange, Franciscan Complex	San Jose	N
ch	Chert in mélange, Franciscan Complex	San Jose	N
db	Diabase and gabbro, Jurassic?	Palo Alto	N
fc	Franciscan Complex, mélange, chert	Monterey	N
fc	Franciscan Complex, Cretaceous and Jurassic--chert,	Palo Alto	N
fg	Franciscan Complex-greenstone, Cretaceous and Jurassic	Palo Alto	Y
fh	Franciscan Complex-argillite, Cretaceous and Jurassic	Palo Alto	N
fl	Franciscan Complex-limestone, Cretaceous and Jurassic	Palo Alto	N
fm	Franciscan Complex-metamorphic rocks Mélange of the Central Belt	San Jose	Y
fm?	Franciscan Complex-metamorphic rocks Mélange of the Central Belt, uncertain	San Jose	N
fmc	Radiolarian chert, Marin Headlands terrane, Lower Cretaceous to Lower Jurassic	San Jose	N
fms	Graywacke-Marin Headlands terrane, Lower Cretaceous	San Jose	Y
fms?	Graywacke-Marin Headlands terrane, Lower Cretaceous, uncertain	San Jose	N
fmv	Basaltic volcanic rocks, Marin Headlands terrain, Lower Jurassic	San Jose	N
fpl	Foraminiferal limestone, Permanente terrane, Upper to Lower Cretaceous	San Jose	N
fpv	Basaltic volcanic rocks, Permanente terrane, Lower Cretaceous	San Jose	N
fpv?	Basaltic volcanic rocks, Permanente terrane, Lower Cretaceous	San Jose	N
fs	Franciscan Complex-sandstone, Cretaceous and Jurassic	Palo Alto	N
fsr	Franciscan Complex-sheared rock mélange, Cretaceous and Jurassic	Palo Alto	N
fy2	Middle unit metagraywacke, slaty mudstone and conglomerate, Yolla Bolly terrane, Cretaceous? and Jurassic	San Jose	N
fyg	Greenstone and bluestone, Yolla Bolly terrane, Cretaceous? And Jurassic	San Jose	N
fys	Metagraywacke, undivided, Yolla Bolly terrane, Cretaceous? And Jurassic	San Jose	N
GP	Gravel pit, Modern	San Jose	N

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
gs	Greenstone blocks in mélange, Central Belt, Franciscan Complex, Lower Tertiary? And Upper Cretaceous	San Jose	N
Jbk?	Landslide area in basalt, andesite and quartz keratophyre breccia, Coast Range ophiolite?, Jurassic	San Jose	Y
Jdw	Cumulate rocks, layered gabbroic through ultramafic rocks, Coast Range Ophiolite, Jurassic	San Jose	N
Jic	Intrusive complex, dioritic to diabasic dikes and sills, Coast Range Ophiolite, Jurassic	San Jose	N
Jsl	Slate of Loma Prieta Peak, Jurassic?	San Jose	N
Jsp	Serpentinite	San Jose	Y
Jsp Qls	Serpentinite in landslide area	San Jose	Y
Jsp?	Serpentinite, uncertain	San Jose	N
Kau	Sandstone, mudstone and conglomerate, Upper Cretaceous	San Jose	N
Kbc	Berryessa Formation—conglomerate, Cretaceous	San Jose	N
Kbc?	Berryessa Formation—conglomerate, Cretaceous, uncertain	San Jose	N
Kbs	Berryessa Formation—sandstone and mudstone, Cretaceous	San Jose	N
Kbs?	Berryessa Formation—sandstone and mudstone, Conglomerate, uncertain	San Jose	N
Kcg	Unnamed conglomerate in Sargent Fault Zone, Cretaceous?	Monterey	N
Kcu	Sandstone, mudstone, and conglomerate, Late Cretaceous	Monterey	N
Kcu	Sandstone, mudstone and conglomerate, Cretaceous	San Jose	N
Kfms	Marin Headlands Terrane, sandstone, Cretaceous	Monterey	N
Kfpg	Permanente Terrane, greenstone agglomerate, Cretaceous	Monterey	N
Kfpl	Permanente Terrane-limestone and chert, Cretaceous	Monterey	N
Kfps	Permanente Terrane, sandstone, Cretaceous	Monterey	N
Khu	Sandstone, mudstone and conglomerate, Late Cretaceous	Monterey	N
KJf	Franciscan Complex, undivided, Cretaceous and Jurassic	Palo Alto	N
KJfm	Mélange, Late Jurassic and/or Early Cretaceous	Monterey	N
KJfmc	Marin Headlands Terrane, chert, Jurassic and Cretaceous	Monterey	N
KJfy	Yolla Bolly Terrane, Middle to Late Jurassic and Early Cretaceous?	Monterey	N
KJk	Knoxville Formation, Lower Cretaceous and Upper Jurassic	San Jose	Y
KJk?	Knoxville Formation, Lower Cretaceous and Upper Jurassic, uncertain	San Jose	N
KJs	Great Valley Sequence, mudstone, Lower Cretaceous and Upper Jurassic	San Jose	N
KJs?	Great Valley Sequence, mudstone, Lower Cretaceous and Upper Jurassic, uncertain	San Jose	N

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
Ksh	Unnamed shale, Upper Cretaceous	Palo Alto	N
Kuc	Great Valley Sequence, conglomerate, Upper Cretaceous	San Jose	N
Kus	Great Valley Sequence, conglomerate, Upper Cretaceous	San Jose	N
Kus?	Great Valley Sequence, conglomerate, Upper Cretaceous, uncertain	San Jose	N
PP	Percolation pond, modern	San Jose	N
Qa	Alluvium, undivided, Quaternary	San Jose	Y
Qc	Colluvium, Quaternary	San Jose	N
Qha	Alluvium, Holocene	San Jose	N
Qhaf	Alluvial fan and fluvial deposits, Holocene	Monterey	N
Qhaf	Alluvial fan and fluvial deposits, Holocene	Palo Alto	Y
Qhaf1	Younger alluvial fan deposits, Holocene	Palo Alto	N
Qhasc	Artificial stream channels	Palo Alto	N
Qhb	Basin deposits, Holocene	Monterey	N
Qhb	Basin deposits, Holocene	Palo Alto	Y
Qhb	Basin deposits, Holocene	San Jose	Y
Qhbm	Bay mud, Holocene	Palo Alto	N
Qhbm	Bay mud	San Jose	N
Qhbs	Basin deposits, salt-affected, Holocene	Palo Alto	N
Qhc	Stream channel deposits, Holocene	San Jose	N
Qhf1	Alluvial fan deposits-younger, Holocene	San Jose	Y
Qhf2	Alluvial fan deposits-older, principal Holocene fans and associated terraces	San Jose	Y
Qhfp	Floodplain deposits, Holocene	Monterey	N
Qhfp	Flood plain deposits, Holocene	Palo Alto	Y
Qhfp	Flood plain deposits, Holocene	San Jose	Y
Qhl	Natural levee deposits, Holocene	Monterey	N
Qhl	Natural levee deposits, Holocene	Palo Alto	Y
Qhl	Natural levee deposits, Holocene	San Jose	Y
Qhsc	Stream channel deposits, Holocene	Palo Alto	Y
Qhsc Qhasc	Stream channel deposits, Holocene, and artificial stream channel deposits, Historic	Monterey	N
Qht	Stream terrace deposits, Holocene	San Jose	Y
Qls	Landslide deposits, Pleistocene and/or Holocene	Monterey	N
Qls	Landslide deposits, Pleistocene and/or Holocene	San Jose	Y
Qls (Tsr)	Landslide deposits, Pleistocene and/or Holocene	Palo Alto	Y
Qls?	Landslide deposits, Pleistocene and/or Holocene, uncertain	San Jose	N
Qoa	Older alluvium, lower-middle Pleistocene?	San Jose	N
Qof	Alluvial fan deposits, middle to upper Pleistocene	San Jose	N
Qof?	Alluvial fan deposits, middle to upper Pleistocene, uncertain	San Jose	N
Qpa	Alluvium, upper Pleistocene	San Jose	N
Qpaf	Alluvial fan and fluvial deposits, Pleistocene	Monterey	N
Qpaf	Alluvial fan and fluvial deposits, Pleistocene	Palo Alto	Y

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
Qpaf1	Alluvial terrace deposits, Pleistocene	Monterey	N
Qpaf1	Alluvial terrace deposits, Pleistocene	Palo Alto	Y
Qpf	Alluvial fan deposits, upper Pleistocene	San Jose	Y
Qpf ls	Landslide in Alluvial fan deposits, upper Pleistocene	San Jose	Y
Qpf?	Landslide in Alluvial fan deposits, upper Pleistocene, uncertain	San Jose	N
Qpoaf	Older alluvial fan deposits, Pleistocene	Palo Alto	N
Qt	Stream terrace deposits, Quaternary	San Jose	N
Qt?	Stream terrace deposits, Quaternary-uncertain	San Jose	N
QTi	Irvington Gravels of Savage (1951), Pleistocene and Pliocene?	San Jose	N
QTm	Merced Formation, lower Pleistocene and upper Pliocene	Palo Alto	N
QTp	Packwood Gravels of Crittenden (1951) Pliocene and Pleistocene	Monterey	N
QTp	Packwood Gravels of Crittenden (1951), Pleistocene? and Pliocene	San Jose	Y
QTp?	Packwood Gravels of Crittenden (1951), Pleistocene? and Pliocene, uncertain	San Jose	N
QTsc	Santa Clara Formation, lower Pleistocene and upper Pliocene	Palo Alto	Y
QTsc	Santa Clara Formation, lower Pleistocene and upper Pliocene	San Jose	Y
QTsc?	Santa Clara Formation, lower Pleistocene and upper Pliocene	San Jose	N
sc	Silica-carbonate rock, Miocene?	San Jose	N
sp	Serpentinite	Monterey	N
sp	Serpentinite	Palo Alto	N
Tb	Butano Sandstone, middle to lower Eocene	Palo Alto	N
Tba	Basalt of Anderson and Coyote Reservoirs, Pliocene	San Jose	N
Tblc?	Conglomerate, lower conglomerate and sandstone member, Butano Sandstone (middle and lower Eocene)—uncertain	Palo Alto	N
Tbm	Brown-weathering mudstone, Eocene	San Jose	N
Tbr	Briones Formation, upper Miocene	San Jose	N
Tbu	Upper sandstone member, Butano Sandstone, middle and lower Eocene	Palo Alto	N
Tbu	Butano Sandstone, sandstone and mudstone, undivided, Eocene	San Jose	N
Tcc	Claremont Formation, upper and middle Miocene	San Jose	Y
Tcm	Sandstone and shale of Loma Chiquita Ridge, Mottled mudstone and sandstone of Mount Chual, lower Eocene	San Jose	N
Tcm?	Sandstone and shale of Loma Chiquita Ridge, Mottled mudstone and sandstone of Mount Chual, lower Eocene, uncertain	San Jose	N
Tgs	Glauconitic sandstone, Paleocene and/or Eocene	Monterey	N
Tgs	Glauconitic sandstone and red mudstone, lower Eocene and/or upper Paleocene	San Jose	N

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
Tgs?	Glauconitic sandstone and red mudstone, lower Eocene and/or upper Paleocene, uncertain	San Jose	N
Tla	Lambert Shale, Oligocene and lower Miocene	Palo Alto	N
Tlad	Ladera Sandstone, upper? and middle Miocene	Palo Alto	Y
Tls	Lambert Shale and San Lorenzo Formation, undivided, lower Miocene, Oligocene, and middle and upper Eocene	Palo Alto	N
Tls	Sandstone and shale of Loma Chiquita Ridge, sandstone and mudstone unit, Eocene	San Jose	N
Tls?	Sandstone and shale of Loma Chiquita Ridge, sandstone and mudstone unit, Eocene, Uncertain	San Jose	N
Tm	Monterey Formation, middle Miocene	Palo Alto	Y
Tmb	Mindego Basalt and related volcanic rocks, Miocene and/or Oligocene	Palo Alto	N
Tms	Monterey Formation, Miocene	Monterey	N
Tms	Unnamed marine sandstone and shale with minor interbeds of siliceous mudstone and semi-siliceous shale, middle to lower Miocene	Palo Alto	Y
Tms	Monterey Shale, middle to lower Miocene	San Jose	Y
Tor	Orinda Formation, upper Miocene	San Jose	N
Torv	Orinda Formation, basalt and andesite interlayered with sandstone and conglomerate	San Jose	N
Tp	Purisima Formation, Pliocene and upper Miocene	San Jose	N
Tpm	Page Mill Basalt, middle Miocene	Palo Alto	N
Tps	Siliceous shale and sandstone of Mount Pajaro, Oligocene and/or Miocene	Monterey	N
Tsc	Conglomerate, sandstone and siltstone of Sargent Hills, Pliocene	Monterey	N
Tscm	Conglomerate, sandstone and siltstone of Sargent Hills, Pliocene-lower marine section	Monterey	N
Tscn	Conglomerate, sandstone and siltstone of Sargent Hills, Pliocene-upper non-marine section	Monterey	N
Tsg	Silver Creek Gravels of Graymer and DeVito, 1993, Pliocene	San Jose	Y
Tsg?	Silver Creek Gravels of Graymer and DeVito, 1993, Pliocene, uncertain	San Jose	N
Tsl	San Lorenzo Formation, Oligocene and upper and middle Eocene	Palo Alto	Y
Tso	Sandstone of Silver Creek, Miocene	San Jose	N
Tsr	Rices Mudstone Member, San Lorenzo Formation, Oligocene and Eocene	San Jose	N
Tsr ls	Landslide in Rices Mudstone Member-San Lorenzo Formation, Oligocene and Eocene	San Jose	Y
Tst	Twobar Shale Member, San Lorenzo Formation, Oligocene and Eocene	San Jose	N
Tts	Temblor Sandstone, middle to lower Miocene	San Jose	Y
Tts?	Temblor Sandstone, middle to lower Miocene, uncertain	San Jose	N
Ttv	Temblor Sandstone, dacitic volcanic and intrusive rocks in upper part, middle Miocene to Oligocene?	San Jose	N

PTYPE	Unit Name	30X60 minute Quadrangle	Radon Survey Data Available
Tu	Unnamed sedimentary rocks, Eocene?	Palo Alto	N
Tu	Sandstone in upper part of Monterey Formation-New Almaden Block, middle to lower Miocene	San Jose	Y
Tus	Unnamed sandstone and conglomerate in Sargent Fault Zone, Miocene	Monterey	N
Tus	Sandstone in upper part of Monterey Formation (middle to lower Miocene	San Jose	Y
Tvo	Andesite of Silver Creek, Miocene	San Jose	N
Tvq	Vaqueros Sandstone (lower Miocene and Oligocene	Palo Alto	N
Tvq	Vaqueros Sandstone and volcanic rocks, lower Miocene and Oligocene	San Jose	N
Tvq?	Vaqueros Sandstone and volcanic rocks, lower Miocene and Oligocene, uncertain	San Jose	N
Tw	Whiskey Hill Formation, lower Eocene	Palo Alto	N
Tws	Shale of Whitehurst Road, Paleocene and/or Eocene	Monterey	N

Total number of geologic map units = 166

Number of units with at least one indoor-radon measurement = 39

Number of units without indoor-radon measurements = 127

APPENDIX F

CDPH Indoor Radon Program Survey Data by Geologic Unit for Santa Clara County, California

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
All Data	CDPH Santa Clara Radon Survey Data	793	--	--	--	2.284	1.6	0.4	39.6	10.3
fg	Franciscan Complex-greenstone (PA)	7	3.2 2.9 2.5	2.3 2.3 1.6	1.1	2.271	2.3	1.1	3.2	0.0
fm	Franciscan Complex-metamorphic rocks (PA); Melange of the Central Belt (SJ)	4	4.4 1.0	0.5	0.4	1.575	0.75	0.4	4.4	25.0
fms (ALL)	Graywacke-Marin Headlands terrane (SJ) ***All***	3	24.5	3.7	3.1	10.433	3.7	3.1	24.5	33.3
fms-L	Graywacke-Marin Headlands terrane (SJ) ***Low Radon Potential***	2	3.7	3.1		3.4	3.4	3.4	3.4	0.0
fms-U	Graywacke-Marin Headlands terrane (SJ) ***Unknown Radon Potential***	1	24.5			24.5	24.5	24.5	24.5	100
fms ls	Graywacke-Marin Headlands terrane (SJ) landslide	1	3.4			3.4	3.4	3.4	3.4	0.0
Jbk?	landslide in volcanics of the Coast Range ophiolite? (SJ)	1	2.2			2.2	2.2	2.2	2.2	0.0
Jsp	Serpentinite (SJ)	2	3.4	1.0		2.2	2.2	1.0	3.4	0.0
Jsp Qls	Serpentinite in landslide area (SJ)	1	2.0			2.0	2.0	2.0	2.0	0.0
Kbc	Berryessa Formation--conglomerate	1	1.2			1.2	1.2	1.2	1.2	0.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
KJk	Knoxville Formation	1	0.8			0.8	0.8	0.8	0.8	0.0
Qa	Alluvium, undivided, Quaternary (SJ)	2	2.1	0.8		1.45	1.45	0.8	2.1	0.0
Qhaf-ALL	Alluvial fan and fluvial deposits, Holocene (PA)	84	19.0	2.1	1.5	2.371	1.7	0.6	19.0	9.5
			9.0	2.1	1.5					
			7.0	2.1	1.4					
	All Data		6.2	2.0	1.4					
			6.1	2.0	1.4					
			5.9	1.9	1.3					
			5.4	1.9	1.3					
			5.1	1.8	1.3					
			3.6	1.8	1.3					
			3.5	1.8	1.3					
			3.4	1.8	1.3					
			3.3	1.7	1.2					
			3.2	1.7	1.2					
			3.1	1.7	1.2					
			3.0	1.7	1.1					
			2.9	1.7	1.1					
			2.9	1.6	1.1					
			2.8	1.6	1.1					
			2.8	1.6	1.0					
			2.6	1.6	1.0					
			2.5	1.6	1.0					
			2.5	1.6	0.9					
			2.4	1.5	0.9					
			2.4	1.5	0.7					
			2.3	1.5	0.7					
			2.3	1.5	0.7					
			2.3	1.5	0.6					
			2.2	1.5	0.6					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhaf-M	Alluvial fan and fluvial deposits, Holocene (PA) ***Moderate Radon Potential Part***	79	19.0 9.0 7.0 6.2 6.1 5.9 5.4 5.1 3.6 3.5 3.3 3.2 3.1 3.0 2.9 2.9 2.8 2.8 2.6 2.5 2.4 2.4 2.3 2.3 2.3 2.1 2.1	2.1 2.0 2.0 1.9 1.8 1.8 1.8 1.8 1.7 1.7 1.7 1.7 1.7 1.6 1.6 1.6 1.6 1.6 1.6 1.5 1.5 1.5 1.5 1.5 1.5 1.5	1.5 1.4 1.4 1.3 1.3 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.1 1.1 1.1 1.1 1.0 1.0 1.0 0.9 0.9 0.7 0.7 0.7 0.6 0.6	2.377	1.7	0.6	19.0	10.1
Qhaf-L	Alluvial fan and fluvial deposits, Holocene (PA) ***Low Radon Potential Part***	5	3.4 2.5	2.2 1.9	1.4	2.28	2.2	1.4	3.4	0.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhb-ALL	Basin deposits, Holocene (PA and SJ)	103	9.9	1.9	1.1	2.019	1.3	0.4	9.9	8.7
			9.2	1.8	1.1					
			9.1	1.8	1.1					
	All Data		7.1	1.7	1.1					
			6.9	1.7	1.0					
	continued on next page		5.7	1.6	1.0					
			5.5	1.6	1.0					
			4.6	1.6	1.0					
			4.4	1.6	1.0					
			3.9	1.6	1.0					
			3.7	1.5	1.0					
			3.7	1.5	0.9					
			3.6	1.5	0.9					
			3.3	1.4	0.9					
			3.2	1.4	0.9					
			3.1	1.3	0.9					
			3.0	1.3	0.9					
			3.0	1.3	0.9					
			2.7	1.3	0.9					
			2.6	1.3	0.9					
			2.6	1.3	0.8					
			2.4	1.3	0.8					
			2.4	1.3	0.8					
			2.3	1.2	0.8					
			2.3	1.2	0.7					
			2.3	1.2	0.7					
			2.3	1.2	0.7					
			2.1	1.2	0.7					
			2.1	1.2	0.7					
			2.1	1.2	0.7					
			2.0	1.2	0.5					
			2.0	1.2	0.5					
			2.0	1.2	0.4					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhb-ALL Continued	***All Data*** continued from previous page		1.9	1.1						
Qhb-M	Basin deposits, Holocene (PA and SJ) ***Moderate Radon Potential Part***	57	9.9 9.2 9.1 6.9 5.7 5.5 4.6 4.4 3.9 3.6 3.2 3.0 2.3 2.3 2.1 2.1 2.0 2.0 1.9	1.8 1.6 1.6 1.5 1.5 1.3 1.3 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.1	1.1 1.1 1.0 1.0 1.0 0.9 0.9 0.9 0.9 0.9 0.8 0.8 0.7 0.7 0.7 0.7 0.5 0.5 0.4	2.184	1.3	0.4	9.9	14.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhb-L	Basin deposits, Holocene (PA and SJ) ***Low Radon Potential Part***	46	7.1 3.7 3.7 3.3 3.1 3.0 2.7 2.6 2.6 2.4 2.4 2.3 2.3 2.1 2.0 1.9	1.9 1.8 1.7 1.7 1.6 1.6 1.6 1.5 1.4 1.4 1.3 1.3 1.2 1.2 1.2	1.1 1.1 1.1 1.0 1.0 1.0 1.0 0.9 0.9 0.9 0.9 0.8 0.8 0.7 0.7	1.815	1.55	0.7	7.1	2.2
Qhf1-ALL	Alluvial fan deposits-younger, Holocene (SJ) ***All***	9	3.2 2.2 1.7	1.6 1.2 1.1	1.1 1.0 0.6	1.522	1.2	0.6	3.2	0.0
Qhf1-L	Alluvial fan deposits-younger, Holocene ***Low Radon Potential Part***	8	3.2 1.7 1.6	1.2 1.1 1.1	1.0 0.6	1.438	1.15	0.6	3.2	0.0
Qhf1-U	Alluvial fan deposits-younger, Holocene ***Unknown Radon Potential Part***	1	2.2			2.2	2.2	2.2	2.2	0.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhf2-ALL	Alluvial fan deposits-older, principal Holocene fans and associated terraces (SJ)	135	39.6	2.4	1.4	2.579	1.9	0.6	39.6	7.4
			16.1	2.4	1.4					
			9.7	2.4	1.4					
			7.6	2.3	1.4					
	All Data		7.3	2.3	1.3					
			6.4	2.3	1.3					
	continued on next page		6.1	2.3	1.3					
			5.7	2.2	1.3					
			5.3	2.2	1.3					
			4.4	2.2	1.3					
			3.9	2.2	1.3					
			3.8	2.2	1.3					
			3.8	2.1	1.3					
			3.6	2.1	1.3					
			3.5	2.1	1.3					
			3.5	2.1	1.2					
			3.5	2.0	1.2					
			3.5	2.0	1.2					
			3.4	2.0	1.2					
			3.3	1.9	1.1					
			3.3	1.9	1.1					
			3.2	1.9	1.1					
			3.1	1.9	1.1					
			3.1	1.9	1.1					
			3.1	1.9	1.1					
			3.0	1.8	1.0					
			3.0	1.8	1.0					
			3.0	1.8	1.0					
			3.0	1.8	1.0					
			2.9	1.7	1.0					
			2.8	1.7	1.0					
			2.8	1.7	1.0					
			2.7	1.7	0.9					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhf2-ALL	***All Data***		2.7	1.7	0.9					
			2.7	1.7	0.9					
continued	continued from previous page		2.6	1.6	0.8					
			2.6	1.6	0.8					
			2.6	1.6	0.8					
			2.6	1.6	0.8					
			2.6	1.5	0.7					
			2.6	1.5	0.7					
			2.6	1.5	0.6					
			2.6	1.5	0.6					
			2.5	1.5	0.6					
			2.5	1.4	0.6					
Qhf2-H	Alluvial fan deposits-older, principal Holocene fans and associated terraces (SJ) ***High Radon Potential Part***	1	0.8			0.8	0.8	0.8	0.8	0.0
Qhf2-M	Alluvial fan deposits-older, principal Holocene fans and associated terraces (SJ)	107	39.6	2.6	1.5	2.796	2.0	0.6	39.6	9.4
			16.1	2.5	1.5					
			9.7	2.5	1.5					
			7.6	2.4	1.5					
	Moderate Radon Potential Part		7.3	2.3	1.4					
			6.4	2.3	1.3					
	continued on next page		6.1	2.3	1.3					
			5.7	2.3	1.3					
			5.3	2.2	1.3					
			4.4	2.2	1.3					
			3.9	2.2	1.3					
			3.8	2.2	1.3					
			3.6	2.2	1.3					
			3.5	2.1	1.3					
			3.5	2.1	1.2					
			3.5	2.1	1.2					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhf2-M	***Moderate Radon Potential Part***		3.4	2.0	1.2					
	continued from previous page		3.3	2.0	1.1					
continued			3.3	2.0	1.1					
			3.2	1.9	1.1					
			3.1	1.9	1.1					
			3.1	1.9	1.1					
			3.0	1.9	1.0					
			3.0	1.8	1.0					
			3.0	1.8	1.0					
			2.9	1.8	1.0					
			2.8	1.7	1.0					
			2.8	1.7	0.9					
			2.7	1.7	0.9					
			2.6	1.7	0.9					
			2.6	1.7	0.8					
			2.6	1.7	0.8					
			2.6	1.6	0.7					
			2.6	1.6	0.6					
			2.6	1.6	0.6					
			2.6	1.5						
Qhf2-L	Alluvial fan deposits-older, principal Holocene fans and associated terraces (SJ)	27	3.8	1.9	1.3	1.781	1.4	0.6	3.8	0.0
			3.5	1.9	1.2					
			3.1	1.8	1.1					
			3.0	1.6	1.0					
	Low Radon Potential Part		2.7	1.4	1.0					
			2.7	1.4	0.8					
			2.4	1.4	0.7					
			2.4	1.4	0.6					
			2.1	1.3	0.6					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhfp-ALL	Flood plain deposits, Holocene (PA and SJ) ***All Data***	33	11.5 4.7 4.6 4.6 2.6 2.4 2.4 2.3 2.2 1.9 1.9	1.8 1.8 1.7 1.6 1.5 1.5 1.3 1.3 1.2 1.1 1.1	1.1 1.1 1.0 1.0 0.8 0.8 0.7 0.6 0.6 0.5 0.5	1.997	1.5	0.5	11.5	12.1
Qhfp-H	Flood plain deposits, Holocene (PA and SJ) ***High Radon Potential Part***	2	11.5	4.6		8.050	8.050	4.6	11.5	100.0
Qhfp-M	Flood plain deposits, Holocene (PA and SJ) ***Moderate Radon Potential Part***	6	4.7 4.6	2.6 1.9	0.7 0.6	2.517	2.25	0.6	4.7	33.3
Qhfp-L	Flood plain deposits, Holocene (PA and SJ) ***Low Radon Potential Part***	25	2.4 2.4 2.3 2.2 1.9 1.8 1.8 1.7 1.6	1.5 1.5 1.3 1.3 1.2 1.1 1.1 1.1	1.1 1.0 1.0 0.8 0.8 0.6 0.5 0.5	1.380	1.3	0.5	2.4	0.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhl-ALL	Natural levee deposits, Holocene (PA and SJ) ***All Data***	58	14.1 6.4 5.7 5.5 5.4 4.7 4.5 4.1 3.4 3.2 2.8 2.7 2.6 2.4 2.4 2.0 2.0 1.9 1.8 1.7	1.7 1.6 1.5 1.5 1.5 1.4 1.4 1.4 1.4 1.2 1.2 1.1 1.1 1.1 1.1 1.0 1.0 1.0 1.0	1.0 0.9 0.9 0.9 0.8 0.8 0.8 0.8 0.8 0.7 0.7 0.7 0.7 0.6 0.6 0.6 0.5 0.5 0.4	2.112	1.3	0.4	14.1	13.8
Qhl-H	Natural levee deposits, Holocene (PA and SJ) ***High Radon Potential Part***	6	6.4 5.5	4.7 2.4	2.0 1.4	3.733	3.55	1.4	6.4	50.0
Qhl-M	Natural levee deposits, Holocene (PA and SJ) ***Moderate Radon Potential Part*** continued on next page	33	14.1 7.7 5.7 5.4 4.5 4.1 2.8 2.7 2.6 1.9	1.7 1.6 1.5 1.5 1.4 1.4 1.4 1.2 1.1 1.1	1.1 1.0 1.0 1.0 1.0 0.9 0.9 0.8 0.8 0.6	2.361	1.4	0.5	14.1	18.2

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhl-M continued	***Moderate Radon Potential Part*** continued from previous page		1.8	1.1	0.5					
Qhl-L	Natural levee deposits, Holocene (PA and SJ) ***Low Radon Potential Part***	19	3.4 3.2 2.0 1.7 1.5 1.2 1.0	0.9 0.8 0.8 0.8 0.7 0.7	0.7 0.7 0.6 0.6 0.5 0.4	1.168	0.8	0.4	3.4	0.0
Qhsc	Qhsc Stream channel deposits, Holocene (PA)	2	9.1	1.3		5.200	5.200	1.3	9.1	50.0
Qht	Stream terrace deposits, Holocene (SJ)	1	0.9			0.9	0.9	0.9	0.9	0.0
Qls	Landslide deposits, Pleistocene and/or Holocene (PA and SJ)	3	2.7	1.1	0.9	1.567	1.1	0.9	2.7	0.0
Qpaf-ALL	Alluvial fan and fluvial deposits, Pleistocene (PA) ***All Data*** continued on next page	137	15.1 9.2 6.8 6.1 5.6 5.1 5.0 4.8 4.4 4.1 4.0 3.9 3.6 3.4 3.2 3.0 3.0 2.8	1.8 1.8 1.8 1.8 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.6 1.6 1.6 1.6 1.5	1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.0 1.0	1.930	1.5	0.5	15.1	8.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qpaf-ALL			2.6	1.5	1.0					
	All Data		2.5	1.5	1.0					
continued	continued from previous page		2.4	1.5	1.0					
			2.4	1.5	0.9					
			2.3	1.5	0.9					
			2.3	1.5	0.9					
			2.3	1.5	0.9					
			2.2	1.5	0.9					
			2.2	1.4	0.9					
			2.2	1.4	0.9					
			2.2	1.4	0.9					
			2.2	1.4	0.9					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.3	0.8					
			2.1	1.3	0.7					
			2.0	1.3	0.7					
			2.0	1.3	0.7					
			2.0	1.3	0.7					
			2.0	1.3	0.7					
			1.9	1.3	0.6					
			1.9	1.3	0.5					
			1.8	1.2	0.5					
			1.8	1.2						
Qpaf-H	Alluvial fan and fluvial deposits,	16	15.1	2.2	1.5	3.300	1.9	0.9	15.1	25.0
	Pleistocene (PA)		6.1	2.0	1.2					
			5.6	1.8	1.2					
	High Radon Potential Part		4.4	1.7	1.1					
	continued from previous page		3.6	1.6	0.9					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qpaf-H continued	***High Radon Potential Part*** continued from previous page		2.8							
Qpaf-M	Alluvial fan and fluvial deposits, Pleistocene (PA) ***Moderate Radon Potential Part***	79	9.2	1.8	1.3	1.944	1.5	0.5	9.2	8.9
			6.8	1.8	1.3					
			5.1	1.8	1.3					
			5.0	1.8	1.2					
			4.8	1.7	1.2					
			4.1	1.7	1.2					
			4.0	1.7	1.2					
			3.9	1.7	1.1					
			3.4	1.7	1.1					
			3.2	1.6	1.1					
			3.0	1.6	1.1					
			2.6	1.5	1.1					
			2.5	1.5	1.1					
			2.3	1.5	1.0					
			2.2	1.5	1.0					
			2.2	1.5	1.0					
			2.2	1.5	0.9					
			2.2	1.4	0.9					
			2.1	1.4	0.9					
			2.1	1.4	0.9					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.0	1.4	0.7					
			2.0	1.4	0.7					
			1.9	1.3	0.5					
			1.9							

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qpaf-L	Alluvial fan and fluvial deposits, Pleistocene (PA) ***Low Radon Potential Part***	40	3.0 2.4 2.4 2.3 2.3 2.1 2.1 2.1 2.0 1.8 1.7 1.7 1.7 1.6	1.5 1.5 1.4 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.1 1.1 1.0	1.0 0.9 0.9 0.9 0.9 0.8 0.8 0.8 0.7 0.7 0.7 0.6 0.5	1.395	1.3	0.5	3.0	0.0
Qpaf-U	Alluvial fan and fluvial deposits, Pleistocene (PA) ***Unknown Radon Potential Part***	2	1.4	0.8		1.1	1.1	0.8	1.4	0.0
SFF (H data for Qhfp + Qhl + Qpaf)	Combined high radon potential alluvial units composing the San Francisquito Alluvial Fan (SFF)	24	15.1 11.5 6.4 6.1 5.6 5.5 4.7 4.6	4.4 3.6 2.8 2.4 2.2 2.0 2.0 1.8	1.7 1.6 1.5 1.4 1.2 1.2 1.1 0.9	3.804	2.3	0.9	15.1	37.5
Qpaf1	Alluvial terrace deposits, Pleistocene (PA)	1	1.7							
Qpf-ALL	Alluvial fan deposits, upper Pleistocene (SJ) ***All*** continued on next page	116	14.9 8.6 7.4 6.5 4.8	1.8 1.8 1.8 1.8 1.8	1.1 1.1 1.1 1.1 1.1	1.938	1.7	0.4	14.9	6.9

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qpf-ALL	**All**		4.7	1.8	1.0					
continued	continued from previous page		4.6	1.8	1.0					
			4.1	1.8	1.0					
			3.8	1.8	1.0					
			3.5	1.8	1.0					
			3.4	1.8	1.0					
			3.3	1.8	1.0					
			3.2	1.8	1.0					
			3.2	1.7	1.0					
			3.0	1.7	0.9					
			2.9	1.7	0.9					
			2.7	1.7	0.9					
			2.7	1.7	0.9					
			2.5	1.7	0.9					
			2.4	1.7	0.8					
			2.3	1.6	0.8					
			2.3	1.5	0.8					
			2.3	1.5	0.8					
			2.3	1.4	0.8					
			2.3	1.4	0.8					
			2.2	1.4	0.8					
			2.2	1.4	0.8					
			2.1	1.4	0.7					
			2.1	1.3	0.7					
			2.1	1.3	0.7					
			2.1	1.2	0.7					
			2.1	1.2	0.7					
			2.0	1.2	0.7					
			2.0	1.2	0.6					
			2.0	1.2	0.6					
			2.0	1.2	0.6					
			1.9	1.2	0.5					
	continued on next page		1.9	1.2	0.4					

Geologic Unit Symbol	**Geologic Unit Name**	**N**	**Indoor-Radon Data pCi/L**			**Mean pCi/L**	**Median pCi/L**	**Low pCi/L**	**High pCi/L**	**% ≥ 4.0 pCi/L**
Qpf-ALL continued	**All** continued from previous page		1.9	1.1						
Qpf-M	Alluvial fan deposits, upper Pleistocene (SJ) ***Moderate Radon Potential Part***	37	14.9 7.4 4.8 4.7 4.6 4.1 3.5 3.4 3.2 3.0 2.5 2.3 2.2	2.1 1.9 1.8 1.8 1.8 1.7 1.7 1.7 1.7 1.7 1.4 1.3	1.2 1.2 1.0 0.9 0.9 0.9 0.8 0.8 0.8 0.7 0.6 0.6	2.476	1.7	0.6	14.9	16.2
Qpf-L	Alluvial fan deposits, upper Pleistocene (SJ) ***Low Radon Potential Part*** continued on next page	77	8.6 3.8 3.3 3.2 2.9 2.7 2.7 2.4 2.3 2.3 2.3 2.3 2.2 2.1 2.1 2.1 2.1 2.0	1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.7 1.7 1.6 1.5 1.5 1.4 1.4 1.4 1.4 1.3 1.2	1.1 1.1 1.1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.8 0.8 0.8 0.8 0.7	1.635	1.4	0.4	8.6	1.3

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qpf-L continued	Alluvial fan deposits, upper Pleistocene (SJ) ***Low Radon Potential Part*** continued from previous page		2.0 2.0 2.0 1.9 1.9 1.8 1.8 1.8	1.2 1.2 1.2 1.2 1.2 1.1 1.1 1.1	0.7 0.7 0.7 0.7 0.6 0.5 0.4					
Qpf-U	Alluvial fan deposits, upper Pleistocene (SJ) Unknown Radon Potential Part	2	6.5	0.8		4.031	3.65	0.8	6.5	50.0
Qpf ls	Landslide in alluvial fan deposits, upper Pleistocene (SJ)	1	0.9			0.9	0.9	0.9	0.9	0.0
QTp	Packwood Gravels of Crittenden (1951), Pleistocene? and Pliocene (SJ)	1	0.4			0.4	0.4	0.4	0.4	0.0
QTsc	Santa Clara Formation, lower Pleistocene and upper Pliocene (PA and SJ)	38	2.8 2.7 2.1 2.0 2.0 1.9 1.8 1.7 1.6 1.6 1.6 1.5 1.5	1.5 1.4 1.4 1.4 1.3 1.2 1.1 1.1 1.1 1.0 1.0 1.0 1.0	0.9 0.9 0.9 0.8 0.8 0.7 0.7 0.7 0.6 0.6 0.5 0.4	1.284	1.15	0.4	2.8	0.0
Tcc	Claremont Formation, upper and middle Miocene (SJ)	2	5.3	2.7		4.0	4.0	2.7	5.3	50.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Tlad	Ladera Sandstone, upper? and middle Miocene (PA)	3	4.5	3.9	3.6	4.0	3.9	3.6	4.5	33.3
Tm	Monterey Formation, middle Miocene, (PA)	17	11.7 10.9 9.1 6.2 4.0 3.5	3.2 2.8 2.6 2.5 2.3 1.3	1.2 1.1 1.1 1.0 0.9	3.847	2.6	0.9	11.7	29.4
Tms	Monterey Shale, middle to lower Miocene (SJ)	12	5.7 5.4 5.2 4.7	4.1 2.9 2.8 2.5	2.3 2.2 1.8 1.4	3.417	2.85	1.4	5.7	41.7
Combined Tm+Tms	Combined PA and SJ Monterey Formation data	29	11.7 10.9 9.1 6.2 5.7 5.4 5.2 4.7 4.1 4.0	3.5 3.2 2.9 2.8 2.8 2.6 2.5 2.5 2.3 2.3	2.2 1.8 1.4 1.3 1.2 1.1 1.1 1.0 0.9	3.669	2.8	0.9	11.7	34.5
Tms_PA	Unnamed marine sandstone and shale with minor interbeds of siliceous mudstone and semi-siliceous shale, middle to lower Miocene (PA)	2	16.2	2.3		9.250	9.25	2.3	16.2	50.0
Tsg	Silver Creek Gravels of Graymer and DeVito, 1993, Pliocene (SJ)	1	0.5			0.5	0.5	0.5	0.5	0.0

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Tsl	San Lorenzo Formation, Oligocene and upper and middle Eocene (PA)	4	24.5 8.5	4.1	1.9	9.750	6.3	1.9	24.5	75.0
Tsr ls	landslide in Rices Mudstone Member-San Lorenzo Formation, Oligocene and Eocene (SJ)	2	9.8	4.4		7.1	7.1	4.4	9.8	100.0
Tts	Temblor Sandstone, middle to lower Miocene (SJ)	1	1.2			1.2	1.2	1.2	1.2	0.0
Tu	Sandstone in upper part of Monterey Formation-New Almaden Block, middle to lower Miocene (SJ)	2	18.8	1.2		12.1	12.1	1.2	18.8	50.0
Tus	Sandstone in upper part of Monterey Formation (middle to lower Miocene) (SJ)	2	1.7	1.2		1.45	1.45	1.2	1.7	0.0
Santa Clara County San Francisquito Alluvial Fan Radon Data for Surficial Geologic Units										
Qhb_SFF	Holocene basin deposits within San Francisquito Fan	15	3.7 3.3 2.7 2.4 2.3	1.9 1.7 1.4 1.3 1.3	1.1 1.0 1.0 1.0 0.9	1.8	1.4	0.9	3.7	0.0
Qhfp_SFF	Holocene flood plain deposits within San Francisquito Fan	4	11.5 4.6	1.8	1.5	4.85	3.2	1.5	11.5	50.0
Qhl_SFF	Holocene levee deposits within San Francisquito Fan	7	6.4 5.5 4.7	2.4 2.4	2.0 1.4	3.59	2.4	1.4	6.4	42.9

Geologic Unit Symbol	**Geologic Unit Name**	**N**	**Indoor-Radon Data pCi/L**			**Mean pCi/L**	**Median pCi/L**	**Low pCi/L**	**High pCi/L**	**% ≥ 4.0 pCi/L**
Qpaf_SFF	Pleistocene alluvial fan deposits within San Francisquito Fan	16	15.1 6.1 5.6 4.4 2.8 2.7	2.2 2.0 1.8 1.7 1.6	1.5 1.2 1.2 1.1 0.9	3.3	1.9	0.9	15.1	25.0
Santa Clara County Radon Data for Surficial Geologic Units Excluding Data from the San Francisquito Alluvial Fan										
Qhb (SFF Rn data removed)	Holocene basin deposits outside of the San Francisquito Alluvial fan continued on next page	83	9.9 9.2 9.1 7.1 6.9 5.7 5.5 4.6 4.4 3.9 3.7 3.6 3.2 3.1 3.0 3.0 2.6 2.3 2.3 2.3 2.1	1.8 1.7 1.6 1.6 1.6 1.6 1.5 1.5 1.5 1.4 1.3 1.3 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.2 1.2	1.1 1.1 1.1 1.0 1.0 1.0 1.0 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.8 0.8 0.8 0.7 0.7 0.7	2.07	1.3	0.4	9.9	10.8

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhb (SFF Rn data removed) continued	Holocene basin deposits outside of the San Francisquito Alluvial fan		2.1	1.2	0.7					
			2.1	1.2	0.7					
			2.0	1.2	0.7					
			2.0	1.2	0.5					
	continued from previous page		1.9	1.2	0.5					
			1.9	1.1	0.4					
			1.8	1.1						
Qhfp (SFF Rn data removed)	Holocene flood plain deposits outside of the San Francisquito Alluvial Fan	32	7.7	1.7	1.0	1.72	1.25	4.7	7.7	9.4
			4.7	1.6	0.8					
			4.6	1.5	0.8					
			2.6	1.3	0.8					
			2.4	1.3	0.7					
			2.3	1.2	0.6					
			2.2	1.1	0.6					
			2.0	1.1	0.6					
			1.9	1.1	0.5					
			1.9	1.1	0.5					
			1.8	1.0						
Qhl (SFF Rn data removed)	Holocene levee deposits outside of the San Francisquito Alluvial Fan	51	14.1	1.5	0.9	1.81	1.1	0.4	14.1	9.8
			5.7	1.5	0.9					
			5.4	1.4	0.8					
			4.5	1.4	0.8					
			4.1	1.4	0.8					
			3.4	1.2	0.8					
			3.2	1.2	0.8					
			2.8	1.1	0.7					
			2.7	1.1	0.7					
			2.6	1.1	0.7					
			2.0	1.1	0.7					
	continued on next page		1.9	1.0	0.6					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
Qhl (SFF Rn data removed) continued	Holocene levee deposits outside of the San Francisquito Alluvial Fan		1.8	1.0	0.6					
			1.7	1.0	0.6					
			1.7	1.0	0.5					
			1.6	1.0	0.5					
	continued from previous page		1.5	0.9	0.4					
Qpaf (SFF Rn data removed)	Pleistocene alluvial fan deposits outside of the San Francisquito Alluvial Fan	124	9.2	1.8	1.2	1.85	1.5	0.5	9.2	6.5
			9.1	1.8	1.2					
			6.8	1.7	1.2					
			5.1	1.7	1.2					
			5.0	1.7	1.2					
			4.8	1.7	1.2					
			4.1	1.7	1.2					
			4.0	1.7	1.1					
			3.9	1.7	1.1					
			3.4	1.7	1.1					
			3.2	1.7	1.1					
			3.2	1.6	1.1					
			3.0	1.6	1.1					
			2.6	1.6	1.1					
			2.6	1.6	1.1					
			2.5	1.6	1.0					
			2.5	1.5	1.0					
			2.4	1.5	1.0					
			2.4	1.5	1.0					
			2.3	1.5	1.0					
			2.3	1.5	0.9					
			2.3	1.5	0.9					
			2.2	1.5	0.9					
	continued on next page		2.2	1.5	0.9					

Geologic Unit Symbol	Geologic Unit Name	N	Indoor-Radon Data pCi/L			Mean pCi/L	Median pCi/L	Low pCi/L	High pCi/L	% ≥ 4.0 pCi/L
	continued from previous page		2.2	1.4	0.9					
			2.2	1.4	0.9					
			2.2	1.4	0.9					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
Qpaf (SFF Rn data removed)	Pleistocene alluvial fan deposits outside of the San Francisquito Alluvial Fan		2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.1	1.4	0.8					
			2.0	1.4	0.7					
continued	continued from previous page		2.0	1.3	0.7					
			2.0	1.3	0.7					
			1.9	1.3	0.7					
			1.9	1.3	0.6					
			1.8	1.3	0.6					
			1.8	1.3	0.5					
			1.8	1.3						

APPENDIX G

Unknown Radon Potential Geologic Units in Santa Clara County With 2015-2016 CDPH Short-term Indoor-radon Data

(PA) = Palo Alto 30X60 minute quadrangle, (SJ) = geologic unit in San Jose 30X60 minute quadrangle

Geologic Unit	Indoor-Radon Data	Radon Potential Designation
fms (SJ) Graywacke-Marin Headlands terrane	R = 0%? N = 1 N ≥ 4.0 pCi/L = 1 Maximum = 24.5 pCi/L	Unknown (Insufficient data available for designation)
Jbk? (SJ) Landslide in volcanics of the Coast Range ophiolite, queried	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 2.2 pCi/L	Unknown (Insufficient data available for designation)
Jsp-Qls (SJ) Serpentinite/landslide area	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 2.0 pCi/L	Unknown (Insufficient data available for designation)
Kbc (SJ) Berryessa Formation-conglomerate	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 1.2 pCi/L	Unknown (Insufficient data available for designation)
KJk (SJ) Knoxville Formation	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 0.8 pCi/L	Unknown (Insufficient data available for designation)
Qhf1 (SJ) Alluvial fan deposits-younger, overlying larger Holocene or older deposits	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 2.2 pCi/L	Unknown (Insufficient data available for designation)
Qhsc (PA) Stream channel deposits	R = 50%? N = 2 N ≥ 4.0 pCi/L = 1 Maximum = 9.1 pCi/L	Unknown (Insufficient data available for designation)
Qls (PA and SJ) Landslide deposits	R = 0%? N = 3 N ≥ 4.0 pCi/L = 0 Maximum = 2.7 pCi/L	Unknown (Insufficient data available for designation)
Qpaf (PA) Pleistocene alluvial fan and fluvial deposits	R = 0%? N = 2 N ≥ 4.0 pCi/L = 0 Maximum = 1.4 pCi/L	Unknown (Insufficient data available for designation)
Qpf (SJ) upper Pleistocene alluvial fan deposits	R = 50%? N = 2 N ≥ 4.0 pCi/L = 1 Maximum = 6.5 pCi/L	Unknown (Insufficient data available for designation)

QTp (SJ) Pleistocene? and Pliocene Packwood gravels of Crittenden (1951)	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 0.4 pCi/L	Unknown (Insufficient data available for designation)
Tsg (SJ) Pliocene Silver Creek Gravels of Graymer and DeVito, 1993	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 0.5 pCi/L	Unknown (Insufficient data available for designation)
Tts (SJ) Temblor Sandstone	R = 0%? N = 1 N ≥ 4.0 pCi/L = 0 Maximum = 1.2 pCi/L	Unknown (Insufficient data available for designation)
Tu (SJ) middle to lower Miocene sandstone in upper part of Monterey Formation-New Almaden Block	R = 0%? N = 2 N ≥ 4.0 pCi/L = 2 Maximum = 18.4 pCi/L	Unknown (Insufficient data available for designation)
Totals	R = 25% N=20 N ≥ 4.0 pCi/L = 5 Maximum = 24.5 pCi/L	

APPENDIX H

Santa Clara County NURE Program Uranium Data and NRCS Soil Data

NURE Program Background

The United States government funded the National Uranium Resource Evaluation (NURE) program between 1975 and 1983. The NURE program goal was to identify new domestic uranium sources (ore deposits) for energy and national defense. NURE exploration activities included using airborne gamma-ray spectral surveys to estimate uranium contents of soil and rock units at points along a grid of flight-lines. Point locations with anomalous elevated uranium concentrations were considered targets for additional investigation to determine if economically recoverable uranium deposits were present. NURE contractors collected soil and stream sediment samples in portions of California for laboratory uranium determinations. Unfortunately, such sampling was not undertaken in Santa Clara County before the NURE program ended.

Airborne Radiometric Data

NURE airborne radiometric data, with modifications by Duval (2000), are used in this radon mapping program. The NURE program collected these data by 1X2 degree quadrangle. The Santa Clara radon map area includes parts of three 1X2 degree quadrangles, San Francisco, San Jose, and Monterey. The data were collected between late November 1979 and early February 1980 using a helicopter equipped with gamma-ray detection and data recording equipment. Gamma-ray measurements were made along flight lines organized in a grid pattern, as shown in Figure H1. The distance between east-west flight lines ranges from about 1 to 4 miles. The north-south flight lines range from about 1.5 to 12.5 miles apart. The survey helicopter flew a few hundred feet above the ground at about 90 miles per hour along these flight lines and recorded 14,031 gamma-ray spectral measurements. The average distance between measurements is about 135 feet. Under survey conditions, each measurement is representative of the gamma-rays produced from the upper 18 inches of surficial material (rock or soil) over an area of about 48,000 square feet, about 1.1 acres (High Life Helicopters, 1980). Approximately 360 miles of NURE flight-line data are available for the Santa Clara County radon study area from three 1X2 degree quadrangles. The NURE uranium data are summarized by geologic map unit in Appendix I. NURE airborne surveys were not usually conducted within national parks or large urban areas. However, the NURE airborne survey was flown over the large urban area in northern Santa Clara County (note the locations of flight lines in Figure H2 in relation to cities).

One of the gamma-ray energies measured during the NURE airborne survey is generated during decay of the isotope bismuth-214. Bismuth-214 is one of the radioactive decay-chain isotopes of uranium-238, which includes radon-222. Bismuth-214 forms soon after radon-222 decays and quickly converts to polonium-214 (see Table 1 in text). The NURE program used bismuth-214 gamma-ray data to calculate

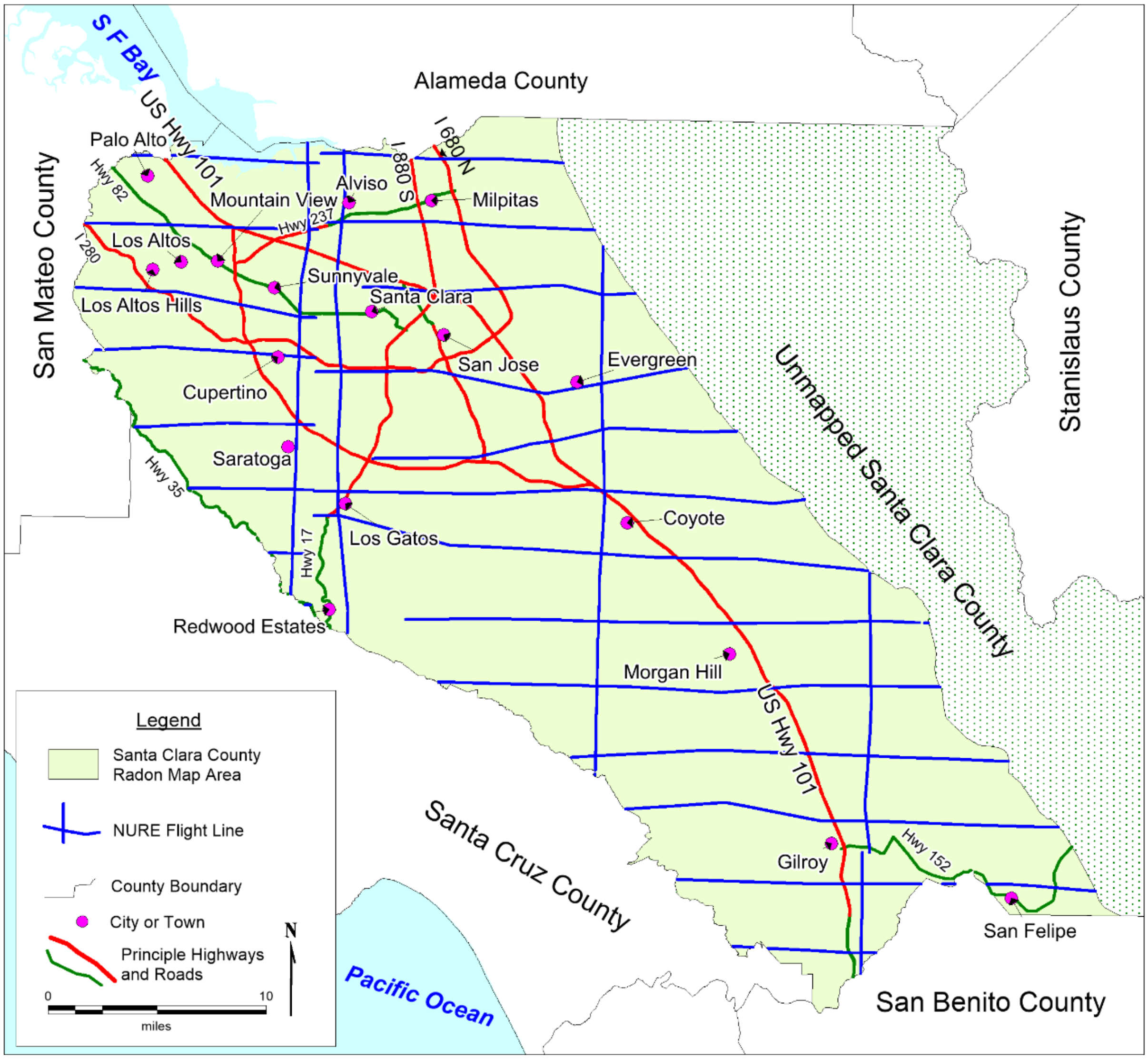


Figure H1. NURE program flight lines for Santa Clara County

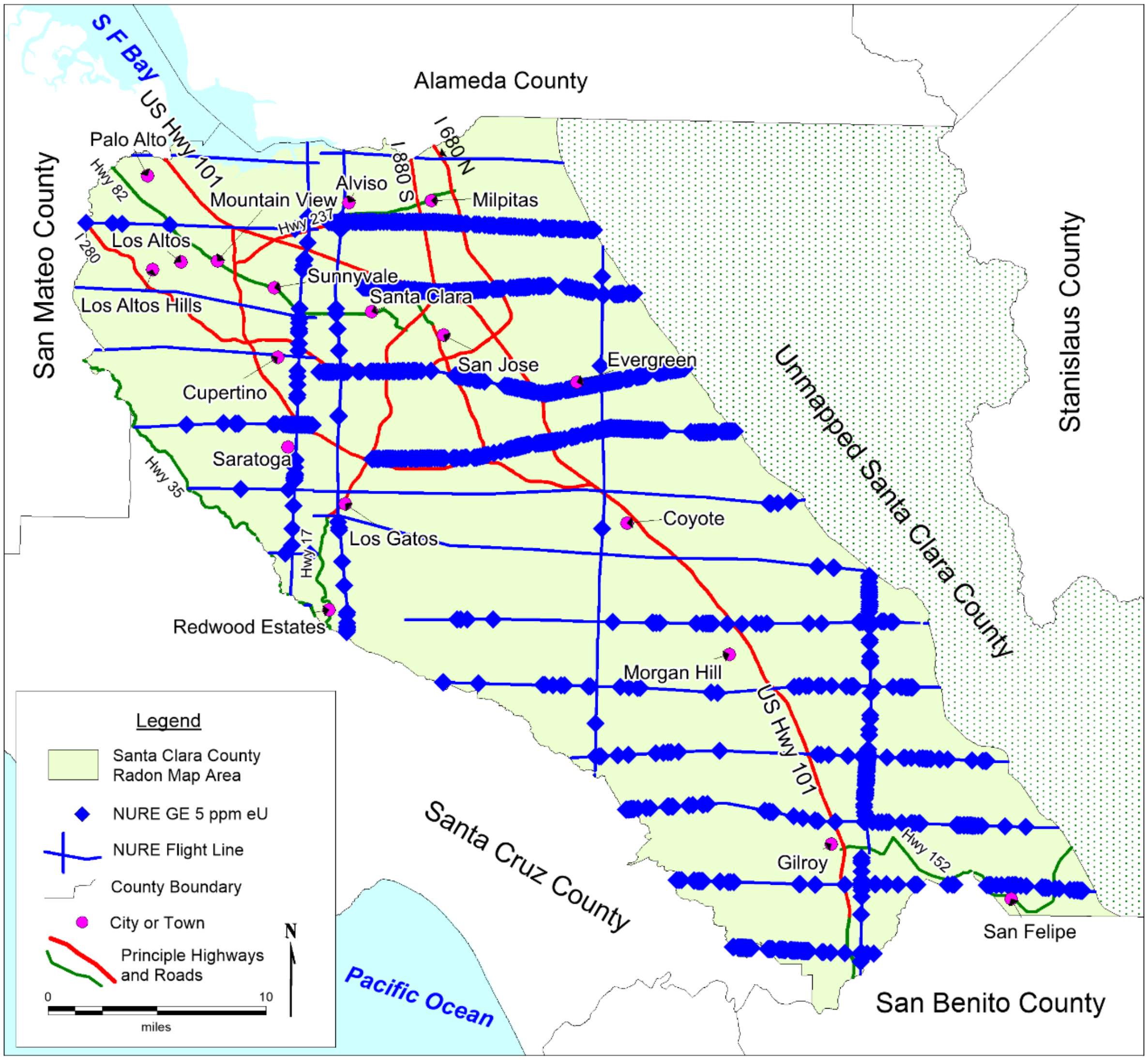
estimates of uranium concentrations in parts-per-million (ppm) of the soil and rock at each flight-line measurement location. Because these uranium concentrations are estimated from bismuth-214 data they are designated as equivalent uranium (eU) data. This distinguishes them from uranium concentration data (U) obtained by subjecting rock or soil samples to laboratory methods that directly measure uranium (U). Note that, in general, soil uranium abundance is like that of the underlying rock from which the soil was developed (Otton, 1992).

Often airborne eU data correlate reasonably well with laboratory U data from surface samples, but occasionally the two differ significantly. One reason is that the uranium decay chain elements radium and/or radon can be mobile in soil and rock and migrate away from the location of their parent uranium if certain geochemical conditions exist at a site. If this happens the bismuth-214 gamma ray signal will be decreased at the parent uranium site. Additionally, the bismuth-214 signal may be elevated at another location where these isotopes have relocated that originally had a lower background uranium concentration. Several additional factors can also influence airborne eU measurements. Soil moisture can negatively impact airborne eU measurements (Grasty, 1997) and complicate their interpretation. Certain weather conditions, such as atmospheric inversion, can also negatively impact airborne eU survey data by causing increased concentrations of radon in the near surface atmosphere. This possibly affected the NURE eU survey data in the San Joaquin Valley portion of the San Jose 1X2 degree quadrangle (Wollenberg and Revzan, 1990; Churchill, 2017). Another limitation of NURE airborne eU surveys are their inability to identify small sized elevated radon potential areas. With NURE airborne survey flight lines spaced several miles apart, smaller sized higher radon potential areas may be present between the flight lines and missed. Because of these complications, the author prefers to treat airborne eU data as a qualitative rather than quantitative indication of elevated radon potential areas.

Although NURE airborne gamma-ray surveys typically avoided densely populated urban areas, the San Francisco and San Jose quadrangle NURE surveys include the major urban areas of Santa Clara County. The high degree of urbanization (buildings, pavement, lawns, and other landscaping) in portions of Santa Clara at the time the data were collected complicates eU data interpretation. Since only gamma rays generated within the shallow near surface depths can be detected, some NURE data may be influenced more strongly by the uranium (radium) content of materials such as asphalt or concrete pavement or road base than by local soil in highly urbanized areas. Original soil profiles in urban areas are often significantly disturbed, creating variability in near-surface soil permeability that could influence eU measurements. Pavement can prevent radon in soil gas from escaping to the atmosphere, causing increased concentrations immediately under pavement that may impact local eU measurements as well as increase indoor-radon concentrations in adjacent buildings.

Airborne eU Data and Indoor-Radon Data

Despite the complexities just mentioned, airborne eU concentrations do often point to areas where geologic units and soils have elevated indoor-radon potentials or where additional indoor-radon testing should be considered. Airborne eU data are particularly helpful for evaluating radon potentials for areas lacking indoor-radon data. For example, portions of flight lines exhibiting elevated eU concentrations associated with certain geologic units suggest those units may have elevated radon potentials away from the flight lines. An often-used simple threshold for dividing higher (anomalous elevated) eU concentrations with higher radon potential from lower eU concentrations is 5.0 ppm (approximately two times crustal background uranium concentration). Five ppm and greater NURE eU flight line data are indicated in Figure H2. The 5.0 ppm and above data occur in several clusters within the Santa Clara radon map area (e.g., south of Milpitas and northeast of Los Gatos, and north-northeast of Gilroy). These elevated data clusters suggest areas with elevated radon potentials. However, Figure H3 shows there is a poor relationship between ≥ 5.0 ppm eU data trends and preliminary radon potential areas based on geologic units with indoor-radon data. Thus, for Santa Clara County the eU 5.0 ppm threshold does not appear to reliably indicate higher or lower



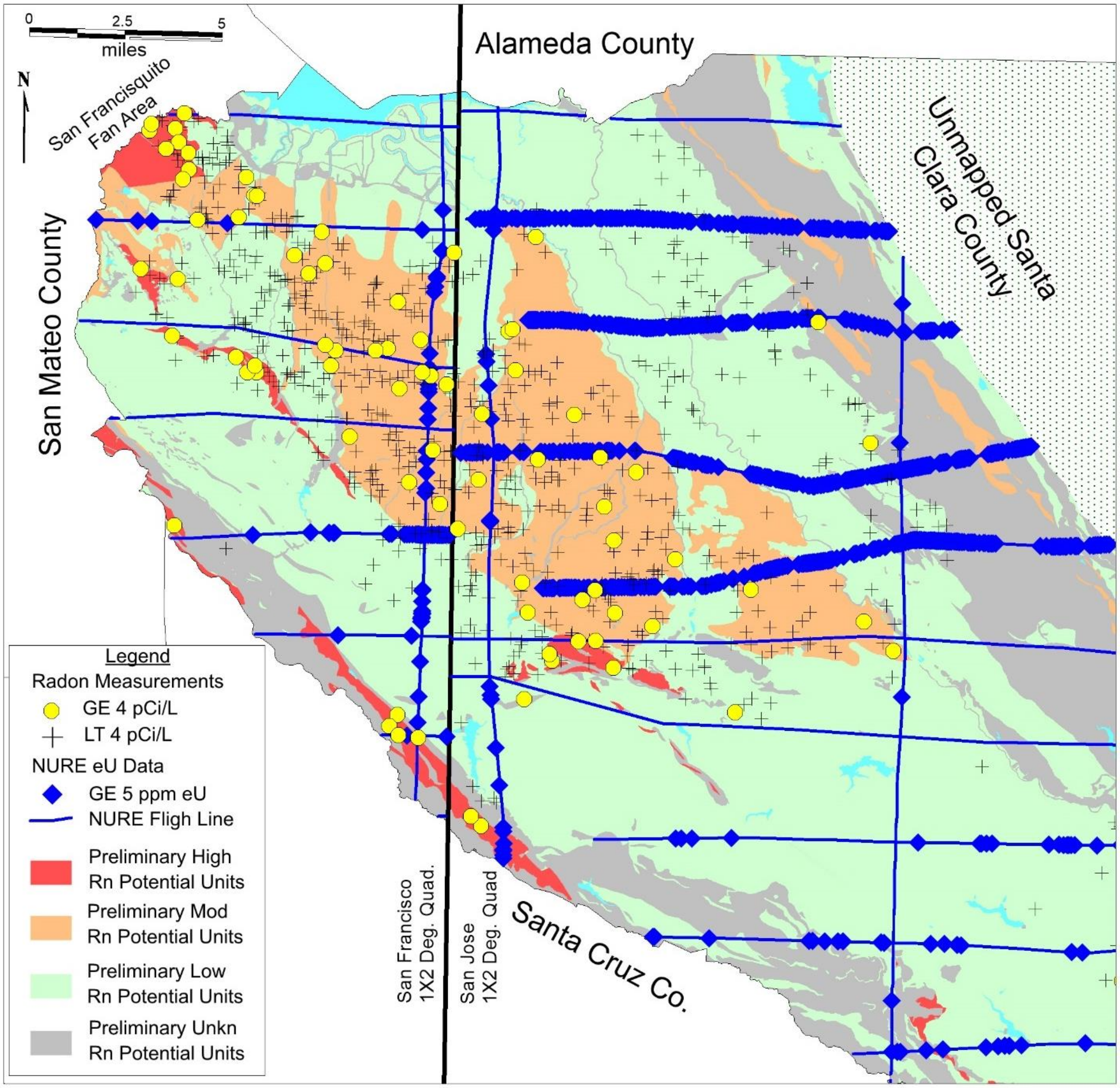
Note, GE = greater than or equal to

Figure H2. NURE program flight lines and equivalent uranium (eU) anomalies

radon potential areas. Alternatively, eU data trends for the geologic units may still support geologic units being assigned to a specific radon potential group if the final eU populations of the various radon potential groups are statistically different.

Comparing Airborne eU Data Populations Between Quadrangles

Appendix J contains statistical summaries of Santa Clara eU populations for the San Francisco, San Jose, and Monterey 1X2 degree quadrangles. These eU populations were compared using the Mann-Whitney Rank Sum test which found that they are



Note: GE = greater than or equal to and LT = less than

Figure H3. NURE eU data, CDPH radon survey data, and preliminary geologic unit radon potential areas

significantly different (Appendix K). The median eU values for the three quadrangle eU populations are 3.2 ppm (Monterey Quadrangle), 2.5 ppm (San Jose Quadrangle) and 1.9 ppm (San Francisco Quadrangle). These results indicate comparison of eU data related to specific geologic units or specific radon potential areas between quadrangles is problematic, and suggests one reason why the 5.0 ppm eU threshold does not work well in Santa Clara County. Some possibilities for the quadrangle eU differences are differences in distribution and areal extent of elevated or low eU geologic units or soils, differences in soil uranium content and permeability between urban and non-urbanized areas (see following section), atmospheric inversion conditions during eU measurement (as previously discussed), or gamma-ray detector calibration differences between quadrangles. Unfortunately, insufficient eU data are available for geologic map units that extend across quadrangle boundaries to further investigate potential causes for these differences.

Comparisons of Airborne eU Data Populations and Preliminary Radon Potential Areas

Because eU populations differ between quadrangles, eU data populations for high, moderate, low, and unknown radon potential groups of geologic units were only compared within quadrangles in this study. Comparisons of eU populations between the preliminary high, moderate, low, and unknown radon potential areas within each 1x2 degree quadrangle were made using the non-parametric Mann-Whitney rank sum test. Test results are summarized here and details are provided in Appendix L.

For San Francisco quadrangle eU:

- The eU data population within moderate radon potential areas is statistically different from those in high, low, or unknown radon potential areas.
- The eU data populations within high and low radon potential areas are not statistically different.
- The eU data population within unknown radon potential areas is statistically different from high, moderate, and low radon potential areas.

For the San Jose quadrangle eU data:

- The eU data population within moderate radon potential areas is statistical different from areas with high, low or unknown radon potential.
- The eU data populations within high and low radon potential areas are not statistically different.
- The eU data population within unknown radon potential areas is statistically different from high, moderate, and low radon potential areas.

For the Monterey quadrangle eU data:

The indoor-radon survey data available for the Monterey quadrangle are too few to identify the presence or absence of high and moderate potential areas here. Preliminary low potential areas identified here are based on a few indoor-radon data and extending the trend of similar low radon potential geologic units from the San Jose quadrangle. All geologic units other than those classified as low are considered to have unknown potential in this portion of Santa Clara County. Comparison of the eU data associated with the preliminary low and unknown radon potential areas here found that these eU populations are statistically different.

The above statistical comparisons of eU populations associated with the different radon potential areas generally support the validity of the latter (the eU populations are statistically different) with one exception. No statistically significant differences were found for eU data in high and low radon potential areas in both the San Francisco and in San Jose quadrangles. Furthermore, the median eU concentration for the moderate radon potential areas of both quadrangles is above that for the high radon potential areas in these quadrangles instead of below as expected.

One possible explanation for the high radon potential zone eU behavior is as follows. Because gamma rays are detected from a 1.1-acre area for each airborne eU measurement, eU data intensities near a high potential area might be diluted because some of the gamma ray signal originates from adjacent lower eU geologic units (e.g., the eU measurement area includes both high and some adjoining moderate or low potential areas). Since high potential areas are smaller size than moderate potential areas, this dilution effect might be relatively more significant for high potential associated eU data. This possibility was investigated by comparing eU data away from high potential area boundaries with eU data near those boundaries to see if significant differences were present to account for a lower high potential eU median. No such differences were identified so it seems this possibility is unlikely. Another possibility is that uranium abundance in the shallow subsurface is not strongly correlated to increased potential for homes with radon concentrations exceeding 4.0 pCi/L. However, the relatively small number of data for high potential areas may be insufficient for the Mann-Whitney rank sum test to document a statistical difference between high and low potential areas, and may produce a population median eU lower than that for moderate potential areas. Additionally, other factors such as uranium concentrations in rocks and soil deeper than 18 inches, below the airborne gamma-ray detection depth, subsurface permeability, or construction characteristics may be more important controls on indoor-radon concentrations in Santa Clara County homes in high potential areas. Natural Resource Conservation Service (NRCS) soil reports typically provide information on near surface soil characteristics including permeability and where urbanization had disrupted the natural soil profile. NRCS soil information for Santa Clara County is presented in the following section and their possible consequences for indoor-radon data and eU data trends are discussed there.

Regarding unknown radon potential areas, the eU populations for these areas are significantly different from the eU populations for areas related to the other radon potential categories in all three 1X2 degree quadrangles. This is not surprising because unknown potential areas typically consist of a mix of geologic unit areas with different radon potentials. Geologic unit areas within the unknown radon potential category can only be reclassified and included in their appropriate radon potential category when additional indoor-radon data and/or uranium data become available.

In summary, the NURE eU data support the presence of high, moderate, and low radon potential areas initially defined only using indoor-radon data and geologic unit boundaries. The small size of high radon potential areas and their limited radon and eU data complicates interpretation of their eU data results. This may be the reason that eU populations for high and low radon potential zones are not statistically different when compared using the Mann-Whitney rank sum test. The NURE eU data also support the likelihood that unknown radon potential areas are composites of smaller high, moderate and/or low radon potential areas.

NRCS Soil Properties and Indoor-Radon

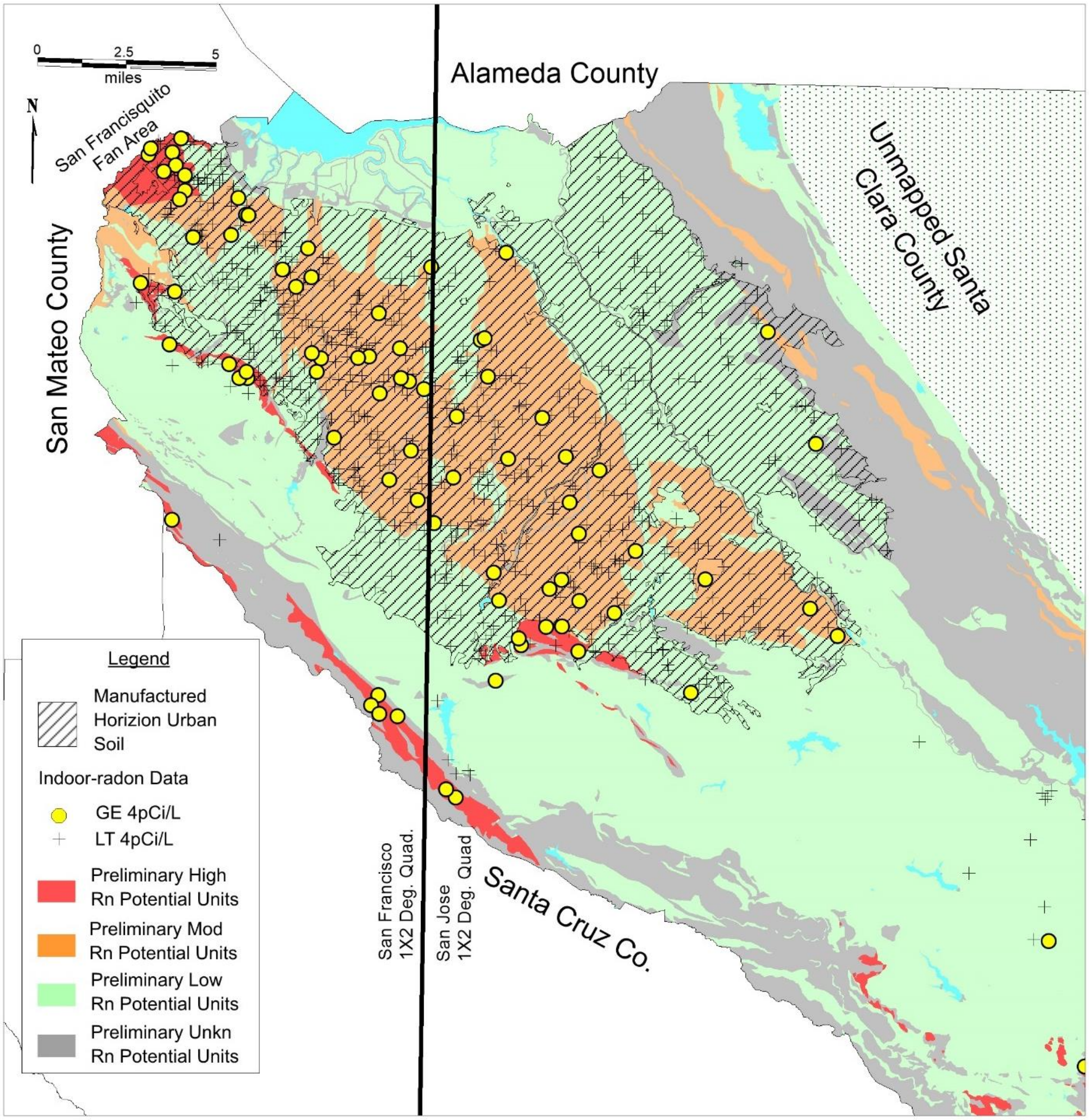
Soil property data are sometimes useful in the process to estimate the radon potential of an area. Radon is more easily released from host minerals and can migrate further within higher permeability soils. Radon release and migration may be significantly restricted in low permeability soils. Soil moisture is also an important factor in radon migration. Radon is more readily released from its point of origin and may migrate further in dry soils than wet soils because it is captured (dissolved) and held in the water (Brookins, 1990, Appleton, 2013). Soils exhibiting moderate to high shrink-swell character may be associated with indoor-radon problems. These soils change permeability, exhibiting low permeability during periods of precipitation and high permeability (cracks) during dry periods because they contain clays that expand or contract in relation to soil moisture. High shrink-swell soils also stress and sometimes crack foundations, creating radon entry pathways into homes.

NRCS reports and maps for the western Santa Clara area (NRCS, 2015) and the eastern Santa Clara area (NRCS, 1974) are the soil information sources for this radon mapping project. Many soil units in western Santa Clara County have been mechanically modified due to urban development. The NRCS report describes these soils as containing a “manufactured layer horizon.” For such soil units, between 40 and 98 percent of their areas contain a “manufactured layer horizon”. The physical properties of manufactured layer horizons can be highly variable. Consequently, the NRCS does not provide permeability, shrink-swell, or other physical property information for these soil units in their reports.

Manufactured Layer Horizon Soils and Radon Survey Data

For convenience, from this point forward this report will use MLH and non-MLH to denote soils containing a manufactured layer horizon and soils not containing a manufactured layer horizon, respectively.

Seventy-two soil units within the Santa Clara County radon map area have one or more associated indoor-radon survey data. Appendix M provides information relationships between different soil units, geologic units and radon data for soil units with radon survey data. Unfortunately, about 84 percent of CDPH Indoor Radon Program survey data are associated with MLH soils having a significant portion of their areas mechanically modified (Figure H4). This prevents evaluation of potential relationships between trends in soil physical properties and indoor-radon data because no physical property information is available for these soils as previously discussed. Data from the remaining 16 percent of indoor-radon survey sites with soil physical property information is insufficient to accurately assess soil property indoor-radon trends for soils without a MLH horizon (i.e., non-MLH soils).



Note: GE = greater than or equal to and LT = less than

Figure H4. NRCS manufactured layer horizon (MLH) soils, CDPH radon survey data above and below 4.0 pCi/L, and preliminary radon potential areas.

Although soil property and indoor-radon trends could not be assessed, there may differences between indoor-radon and eU populations associated with MLH soils and those populations associated with non-MLH soils. Descriptive statistics for radon and eU populations associated with MLH and non-MLH soils are listed in appendices M, N, O, P, Q and R. The availability of indoor-radon data and NURE airborne eU data for the Santa Clara County urban area provides a rare opportunity to investigate the relationship of radon and eU data and urban development by looking at the eU populations for MLH and non-MLH soil units. Comparisons of these populations within MHL and non-MLH soil areas were made using the Mann-Whitney rank sum test. The results for these comparisons are provided in Appendices S and T and are briefly summarized here. Note that no MLH soils are identified in the NRCS report for the Monterey quadrangle portion of Santa Clara County. Consequently, radon data and eU data comparisons for MLH and non-MLH soils are not available for this part of Santa Clara County.

Comparisons of radon data populations associated with MLH soils and non-MLH soils are in Appendix T and summarized here:

1. The Santa Clara County radon populations for MLH soils and non-MLH soils are statistically different ($P \leq 0.006$). The median radon concentration for MLH soil areas is 2.1 pCi/L. These areas are located on alluvial fans, natural levee, and basin alluvium. The median radon concentration for non-MLH soil areas is 1.55 pCi/L. These areas are in bedrock and nearby shallow soil areas and in soil associated with the San Francisquito alluvial fan.

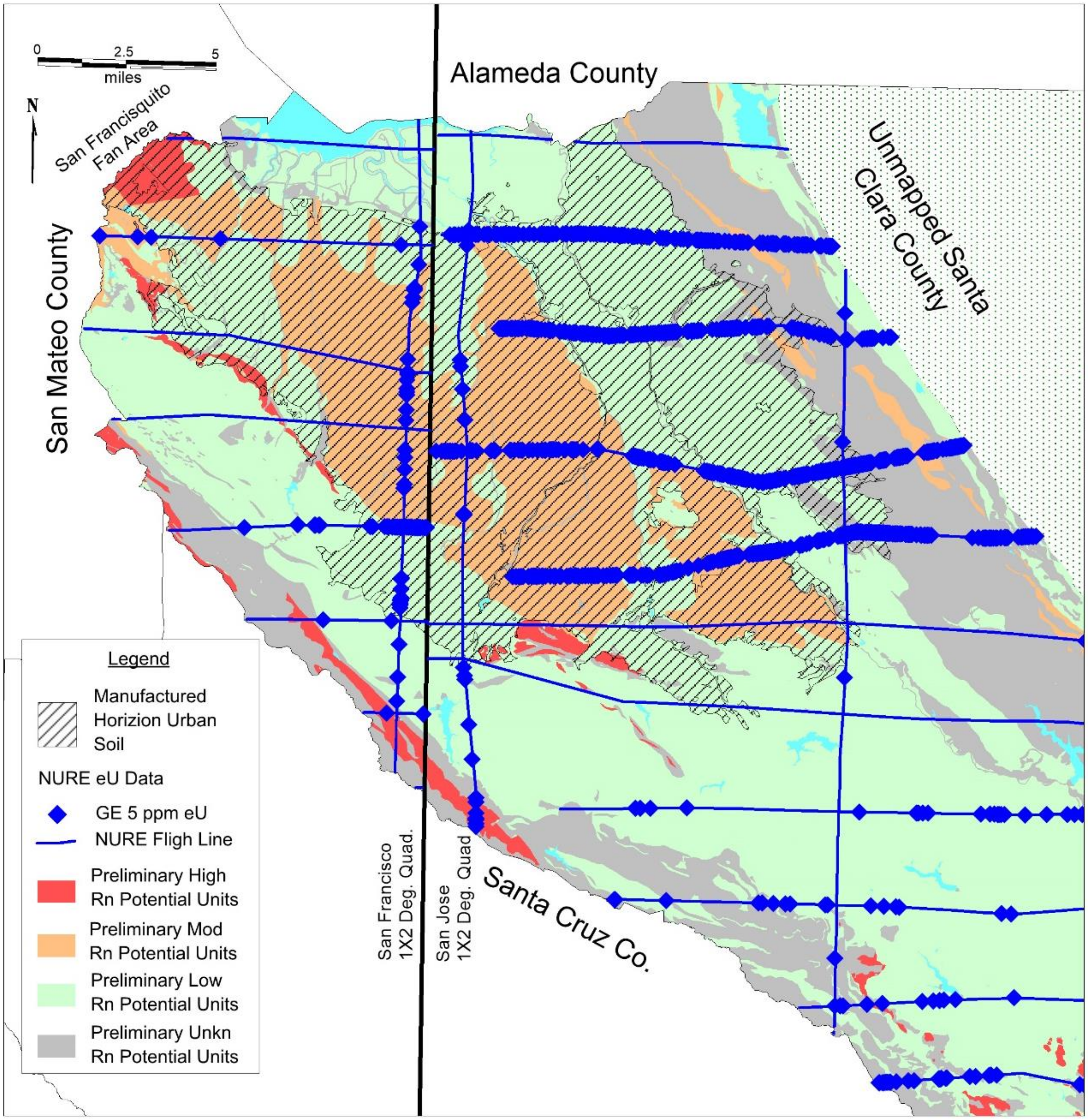
2. Analysis of the radon populations for MLH soil and non-MLH soil areas in preliminary high, moderate, low, and unknown radon potential areas did not identify any statistically significant differences.

Finding 2 seems counter to finding 1 (i.e., MLH and non-MLH soil radon populations are statistically different, but high potential radon populations for MLH and non-MLH; moderate potential radon populations for MLH and non-MLH soils, etc. are not statistically different). Possibly, the small number of radon data for several of the soil-radon potential categories are responsible for these conflicting statistical results.

The above statistical test results suggest, but do not prove, that some feature(s) in the more urbanized areas (e.g., pavement type and extent, building type, landscaping, alluvial deposit type, and origin) may contribute to slightly higher indoor-radon concentrations there. Additional research would be required to prove or refute this possibility.

Manufactured Layer Horizon Soils and Airborne eU data

Potential relationships between MLH and non-MLH soils and NURE airborne eU data were also evaluated using the same approach as for indoor-radon data. One difference is that many more eU data are available in non-MLH soil areas than indoor-radon data for those areas (see Figure H5). Again, because no MLH soils are identified in the NRCS report for the Monterey quadrangle portion of Santa Clara County no eU data from that part of the county are included in these comparisons. Because of differences in eU populations between the San Francisco and San Jose previously discussed, comparisons of the eU data populations of MLH and non-MLH soils are only made within the San Francisco and San Jose quadrangles and not between them. Mann-Whitney rank sum test comparisons of the eU data populations associated with MLH soils and non-MLH soils are in Appendix U and summarized here:



Note: GE = greater than or equal to

Figure H5. NRCS manufactured layer horizon soils, NURE Program eU Survey Flight Lines, eU data ≥ 5.0 ppm, and preliminary radon potential areas.

1. Within the San Francisco Quadrangle, the eU populations for MLH soils and non-MLH soils are statistically different ($P \leq 0.001$). The median eU concentration for MLH soils is 2.3 ppm. The median eU concentration for non-MLH soils is 1.65 ppm.

2. Within the San Jose Quadrangle, the eU populations for MLH soils and non-MLH soils are statistically different ($P \leq 0.001$). The median eU concentration for MLH soils is 3.6 ppm. The median eU concentration for non-MLH soils is 2.3 ppm.

For both the San Francisco and San Jose Quadrangles, MLH soil eU populations are statistically different from non-MLH soil eU soil populations and MLH soils have higher median eU concentrations. There are several possible causes for this eU relationship. Increased pavement in urban areas may block radon escaping from soil to the atmosphere and increase near-surface soil radon concentrations. Some pavement or other construction materials in urban areas may have baseline uranium (i.e., radium) concentrations slightly above baseline uranium concentrations in less urbanized areas. Evaluating these and other possibilities for the soil eU population differences would require significant work beyond the scope of this study.

Mann-Whitney rank sum test comparisons of the preliminary radon potential zones for eU data populations associated with MLH soils and non-MLH soils are in Appendix U and summarized here:

3. Within the San Francisco Quadrangle, the eU populations for MLH and non-MLH soils in high, moderate, and unknown potential areas are not statistically different. The eU populations for MLH and non-MLH soils in low potential areas are statistically different.

4. Within the San Jose Quadrangle, the eU populations for MLH and non-MLH soils in high and moderate potential areas are not statistically different. The eU populations for MLH and non-MLH soils in low potential and unknown potential areas are statistically different.

Lack of statistically significant differences between eU populations for MLH soil and non-MLH soils for high, moderate, and unknown potential geologic units in the San Francisco quadrangle may result from relatively small eU population sizes for these areas. Lack of statistically significant differences between eU populations for MLH soils non-MLH soils for high and moderate potential geologic units in the San Jose quadrangle likely also result from relatively small eU population sizes for these areas.

APPENDIX I Santa Clara County Radon Study Area eU Data

Data ≤ 0 removed

Unit Symbol	Unit Name*	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
af	Artificial fill (Historic)	Palo Alto	26	1.5	0.1	3.9	F F	0
af	Artificial fill (Modern)	San Jose	21	1.5	0.3	3.1	N F	0
af-All			47	1.5	0.1	3.9	F F	0
afl	Artificial levee fill (Historic)	Palo Alto	19	1.6	0.2	2.7	N F	0
alf	Artificial levee fill (Historic)	Monterey	21	3.4	0.1	5.8	N LN	14.29
alf-ALL			40	2.45	0.2	5.8	N F	7.50
ch	Chert and metachert, Franciscan Complex mélange ARB	San Jose	35	3.7	0.4	5.8	N F	8.57
db	Diabase and gabbro	Palo Alto	70	1.95	0.2	5.7	F F	4.29
fc	Chert, Franciscan Complex	Palo Alto	1	1.4	1.4	1.4	?	0
fg	Greenstone, Franciscan Complex	Palo Alto	233	1.4	0.1	5.8	F F	1.29
fh	Argillite, Franciscan complex	Palo Alto	5	1.7	0.6	2.3	N LN	0
fm	Mélange, Franciscan Complex NAB, SCB, ARB	San Jose	1048	1.9	0.1	9.5	F F	6.11
fmc	Radiolarian chert, Franciscan Complex Permanente terrane NAB	San Jose	8	1.85	0.2	3.6	N LN	0
fms	Graywacke, Franciscan Complex Permanente terrane NAB	San Jose	292	1.9	0.1	7.6	F F	5.82
fmv	Basaltic volcanic rocks, Franciscan Complex Permanente terrane (Lower Jurassic) NAB	San Jose	101	1.4	0.2	5.9	F F	0.99
fpl	Foraminiferal limestone, Franciscan Complex Permanente terrane NAB	San Jose	10	1.55	0.8	4.0	N LN	0
fpv	Basaltic volcanic rocks, Franciscan Complex Permanente terrane (Lower Cretaceous) NAB	San Jose	404	1.7	0.1	6.0	F F	1.49
fs	Sandstone, Franciscan Complex	Palo Alto	84	2.0	0.4	6.0	F F	2.38
fsr	Sheared rock (mélange), Franciscan Complex	Palo Alto	165	1.3	0.1	4.5	F F	0

Unit Symbol	Unit Name	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
fy2	Middle Unit metagraywacke, slaty mudstone and conglomerate, Franciscan Complex, Yolla Bolly terrane MHB	San Jose	28	2.75	1.1	5.0	N F	3.57
fys	Metagraywacke, undivided, Franciscan Complex, Yolla Bolly terrane MHB	San Jose	52	3.7	0.1	7.4	N F	19.23
GP	Gravel pit, Santa Clara Valley	San Jose	2	2.4	2.4	2.4	F F	0
gs	Greenstone, Franciscan Complex mélange NAB, ARB	San Jose	24	1.6	0.3	4.5	N LN	0
Jbk	Basalt, andesite and quartz keratophyre, Coast Range Ophiolite SAB ARB	San Jose	48	0.95	0.2	4.2	F F	0
Jdw	Cumulate rocks (mafic-ultramafic, partially to extensively serpentinized) Coast Range Ophiolite SAB	San Jose	48	1.2	0.3	3.9	F LN	0
Jic	Intrusive complex, dioritic to diabasic, Coast Range Ophiolite SAB ARB	San Jose	11	1.0	0.2	2.5	N LN	0
Jsl	Slate of Loma Prieta Peak SAB	San Jose	1	1.2	1.2	1.2	?	0
Jsp	Serpentinized ultramafic rocks, Coast Range Ophiolite NAB CB ARB	San Jose	228	1.2	0.1	6.6	F F	3.51
Jsp?	Serpentinized ultramafic rocks, Coast Range Ophiolite NAB CB ARB	San Jose	91	1.6	0.1	5.7	F F	2.20
Kau	Sandstone, mudstone and conglomerate ARB	San Jose	19	1.9	0.1	4.3	N F	0
Kbc	Berryessa Formation conglomerate ARB	San Jose	56	4.1	0.7	7.6	N F	21.43
Kbc?	Berryessa Formation conglomerate ARB	San Jose	1	5.0	5.0	5.0	?	100.0
Kbs	Berryessa Formation sandstone and mudstone ARB	San Jose	82	4.55	0.1	10.7	F F	41.46

Unit Symbol	Unit Name	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
Kcu	Sandstone, mudstone and conglomerate CB	San Jose	913	2.6	0.1	7.5	F F	7.01
Kcu	Sandstone, mudstone and conglomerate (Late Cretaceous)	Monterey	96	3.6	0.2	8.8	N F	17.71
Kcu-all			1009	2.7	0.1	8.8	F F	8.03
Kfpg	Greenstone agglomerate, Franciscan Complex (Permanente Terrane)	Monterey	133	2.0	0.2	7.4	F F	1.5
Kfps	Sandstone, Franciscan Complex (Permanente Terrane)	Monterey	39	3.0	0.7	6.3	N F	5.13
KJfm	Sandstone, Franciscan Complex (Marine Headlands Terrane)	Monterey	2	2.7	2.2	3.2	N LN	0
KJfy	Yolla Bolly Terrane, Franciscan Complex	Monterey	39	3.5	1.3	6.2	F LN	23.08
KJk	Knoxville Formation SCB ARB	San Jose	50	5.3	0.2	8.9	N F	54.00
KJk?	Knoxville Formation SCB ARB	San Jose	19	3.2	0.3	5.6	N F	5.26
KJs	Mudstone SAB	San Jose	8	1.9	0.5	6.6	N LN	12.50
Kuc	Great Valley sequence conglomerate SAB	San Jose	68	2.2	0.2	4.9	N F	0
Kuc	Great Valley sequence sandstone and shale	Monterey	1	3.9	3.9	3.9	?	0
Kuc-all			69	2.2	0.2	4.9	N F	0
Kus	Great Valley sequence sandstone and shale SAB	San Jose	96	1.95	0.1	6.8	F F	7.29
Kus?	Great Valley sequence sandstone and shale SAB	San Jose	18	2.9	0.7	5.7	N F	5.56
PP	Percolation pond, Santa Clara Valley	San Jose	4	3.2	2.2	4.1	N LN	0
Qa	Alluvium, undivided	San Jose	70	2.4	0.1	6.4	N F	5.71
Qc	Colluvium	San Jose	10	1.9	1.0	3.1	N LN	0
Qha	Alluvium (Holocene)	San Jose	65	2.9	0.1	9.9	F LN	21.54

Unit Symbol	Unit Name	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
Qhaf	Alluvial fan and fluvial deposits (Holocene)	Palo Alto	304	2.3	0.1	8.9	F F	3.29
Qhaf	Alluvial fan and fluvial deposits (Holocene)	Monterey	10	4.8	1.8	7.8	N LN	50.00
Qhaf-all			314	2.3	0.1	8.9	F F	4.78
Qhaf1	Younger alluvial fan deposits	Palo Alto	2	0.95	0.7	1.2	N LN	0
Qhasc	Artificial stream channels (Historic)	Palo Alto	2	1.6	1.2	2.0	N LN	0
Qhb	Basin deposits	Palo Alto	230	2.05	0.1	6.5	F F	2.17
Qhb	Basin deposits	San Jose	709	3.0	0.1	21.7	F F	17.07
Qhb	Basin deposits	Monterey	39	3.2	1.3	5.4	N LN	10.26
Qhb-all			979	2.8	0.1	21.7	F F	13.28
Qhbm	Bay mud	Palo Alto	166	1.3	0.1	4.0	F F	0
Qhbm	Bay mud	San Jose	116	1.9	0.1	7.0	F F	7.76
Qhbm-all			282	1.5	0.1	7.0	F F	3.19
Qhbs	Basin deposits, salt-affected	Palo Alto	8	2.15	1.0	5.6	N LN	12.50
Qhc	Stream channel deposits (Holocene)	San Jose	58	3.8	0.3	7.8	F F	27.59
Qhf1	Alluvial fan deposits-younger (Holocene)	San Jose	81	4.7	0.6	7.4	F F	39.51
Qhf2	Alluvial fan deposits-older (Holocene)	San Jose	816	3.2	0.1	9.5	F F	14.71
Qhfp	Floodplain deposits	Palo Alto	118	2.3	0.3	5.0	F F	0.85
Qhfp	Floodplain deposits	San Jose	181	4.6	0.5	7.9	F F	36.46
Qhfp	Floodplain deposits	Monterey	273	3.1	0.1	6.9	F F	5.86
Qhfp-all			572	3.3	0.1	7.9	N F	14.51
Qhl	Natural levee deposits	Palo Alto	57	1.8	0.1	3.5	N F	0
Qhl	Levee deposits (natural)	San Jose	512	4.0	0.1	8.2	F F	27.73
Qhl	Natural levee deposits	Monterey	24	3.2	0.1	5.9	N F	4.17
Qhl-all			593	3.8	0.1	8.2	F F	24.11
Qhsc	Stream channel deposits	Palo Alto	14	1.3	0.5	5.8	F LN	7.14
Qhsc?	Stream channel deposits	Monterey	4	2.9	2.2	4.7	N LN	0
Qht	Stream terrace deposits	San Jose	9	5.7	4.6	8.1	N LN	88.89
Qls	Landslide deposits (Quaternary)	San Jose	548	2.8	0.1	9.7	F F	10.95
Qls?	Landslide deposits (Quaternary)	San Jose	3	2.3	0.9	2.3	N LN	0

Unit Symbol	Unit Name	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
Qof	Alluvial fan deposits (middle to upper Pleistocene)	San Jose	53	4.3	0.1	8.6	N F	43.40
Qpa	Alluvium (upper Pleistocene)	San Jose	44	2.45	0.3	7.8	F F	15.91
Qpaf	Alluvial fan and fluvial deposits (Pleistocene)	Palo Alto	636	2.4	0.1	10.2	F F	7.55
Qpaf	Alluvial fans and fluvial deposits (Pleistocene)	Monterey	59	2.6	0.8	6.1	N LN	3.39
Qpaf-all			695	2.4	0.1	10.2	F F	7.19
Qpf	Alluvial Fan Deposits (Upper Pleistocene)	San Jose	1375	2.7	0.1	10.1	F F	14.18
Qpaf1?	Alluvial Terrace Deposits (Pleistocene)	Monterey	11	3.4	0.9	6.4	N LN	27.27
Qpoaf	Older alluvial fan deposits (Pleistocene)	Palo Alto	14	3.1	1.9	5.0	N LN	7.14
QTi	Irvington Gravels of Savage (1951) ARB	San Jose	10	2.3	1.1	4.1	N LN	0
QTp	Packwood Gravels of Crittenden (1951) SCB	San Jose	178	2.0	0.2	8.6	F LN	12.36
QTsc	Santa Clara Formation	Palo Alto	234	2.05	0.1	6.9	F F	1.71
QTsc	Santa Clara Formation NAB	San Jose	124	1.85	0.1	5.0	N F	0.81
QTsc-all			358	2.0	0.1	6.9	F F	1.40
sc	Silica carbonate rock NAB SAB SCB	San Jose	9	2.4	0.5	4.7	N LN	0
sp	Serpentinite in mélange (fm) Franciscan Complex SCB ARB	Palo Alto	3	1.8	1.0	2.2	N LN	0
sp	Serpentinite, Coast Range Ophiolite	Monterey	4	2.1	1.3	3.2	N LN	0
sp ALL			7	1.8	1.0	3.2	N LN	0
Tb	Butano Sandstone	Palo Alto	17	1.0	0.1	2.6	N LN	0
Tba	Basalt of Anderson and Coyote Reservoirs SCB	San Jose	35	2.6	0.7	6.1	N F	5.71
Tblc?	Conglomerate, Butano Sandstone	Palo Alto	8	2.05	0.3	3.4	N LN	0
Tbm	Brown-weathering mudstone CB	San Jose	1	2.7	2.7	2.7	?	0
Tbr	Briones Formation CB ARB	San Jose	260	3.2	0.1	8.3	F F	13.85
Tcc	Claremont Formation CB ARB MHB	San Jose	104	3.65	0.2	8.6	N F	17.31

Unit Symbol	Unit Name	30X60 minute Quadrangle	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
Tcm	Mottled mudstone and sandstone of Mount Chual SAB	San Jose	100	2.1	0.2	6.0	F F	2.00
Tcm?	Mottled mudstone and sandstone of Mount Chual SAB	San Jose	8	2.45	1.1	3.0	N F	0
Tgs	Glauconitic sandstone and red mudstone CB	San Jose	80	2.75	0.1	8.9	N F	8.75
Tgs	Glauconitic sandstone	Monterey	12	3.95	2.8	5.5	N LN	25.00
Tgs-all			92	2.9	0.1	8.9	N F	10.87
Tla	Lambert Shale	Palo Alto	4	0.5	0.3	2.2	N LN	0
Tlad	Ladera Sandstone	Palo Alto	14	1.8	0.6	4.2	N LN	0
Tls	Lambert Shale and San Lorenzo Formation, Undivided	Palo Alto	3	0.8	0.1	1.7	N LN	0
Tls	Sandstone and mudstone-Shale and sandstone of Highland Way SAB	San Jose	160	1.9	0.1	10.4	F F	7.50
Tls-all			163	1.9	0.1	10.4	F F	7.36
Tm	Monterey Shale	Palo Alto	1	1.9	1.9	1.9	?	0
Tms	Monterey Shale NAB	San Jose	56	2.0	0.3	6.2	F F	7.14
Tm+Tms-all	Monterey Shale		57	2.0	0.3	6.2	F F	7.02
Tmss	Sandstone of Mount Madonna	Monterey	58	4.0	0.9	6.9	N F	24.14
Tor	Orinda Formation ARB	San Jose	33	3.8	0.5	6.6	N F	15.15
Torv	Orinda Formation basalt and andesite ARB	San Jose	3	4.4	4.3	4.5	N LN	0
Tpm	Page Mill Basalt	Palo Alto	3	1.9	0.5	2.8	N LN	0
Tps	Siliceous shale and sandstone of Mount Pajaro	Monterey	110	4.4	1.7	9.0	N LN	40.00
Tscm	Lower marine section of Tsc-conglomerate, sandstone, and siltstone of Sargent Hills	Monterey	95	3.5	0.1	10.2	F LN	28.42
Tscn	Upper non-marine section of Tsc-conglomerate, sandstone, and siltstone of Sargent Hills	Monterey	10	2.9	0.7	4.3	N F	0

Unit Symbol	Unit Name	30X60 minute Quadrangle ^	N eU data	Median eU ppm	Low eU ppm	High eU ppm	Data Distribution**	% R ≥ 5 ppm eU
Tsg	Silver Creek Gravels of Graymer and DeVito (1993) SCB	San Jose	111	1.6	0.1	7.2	F F	9.01
Tsg?	Silver Creek Gravels of Graymer and DeVito (1993) SCB	San Jose	5	2.5	1.1	4.3	N LN	0
Tsl	San Lorenzo Formation	Palo Alto	92	2.2	0.1	5.2	N F	1.09
Tts	Temblor Sandstone NAB CB MH	San Jose	90	2.55	0.2	9.9	F F	20.00
Tu	Unnamed sedimentary rocks (Eocene?)	Palo Alto	26	2.4	0.4	4.5	N F	0
Tvq	Vaqueros Sandstone	Palo Alto	153	1.6	0.1	4.8	F F	0
Tvq	Vaqueros Sandstone SCB	San Jose	2	2.0	0.5	3.5	N LN	0
Tvq-all			155	1.6	0.1	4.8	F F	0
Tw	Whiskey Hill Formation	Palo Alto	31	2.5	0.4	5.3	F F	6.45

Total eU data points = 14,031

*Bedrock tectonic block abbreviations for geologic units within the San Jose 1:100,000 quadrangle: ARB-Alum Rock Block, CB-Coyote Block, MHB-Mount Hamilton Block, NAB-New Almaden Block, SCB-Santa Cruz Block, SAB-Sierra Azul Block

**Data Frequency Distribution Column Codes

F (first entry) = failed Shapiro-Wilk normality test
F (second entry) = log (ln) transformed data failed Shapiro-Wilk normality test
N (first entry) = passed Shapiro-Wilk normality test
LN (second entry) = log (ln) transformed data passed Shapiro-Wilk normality test

Note: Data distribution for small data sets is inconclusive. They will typically pass both normality and lognormality tests.

^NURE Program airborne eU data surveys are by 1 X 2-degree quadrangle (1:250,000-scale); San Francisco, San Jose and Monterey for the Santa Clara radon map. However, the U.S. Geological Survey geologic maps are on 30X60 minute quadrangles, the Palo Alto, San Jose and Monterey at 1:100,000-scale. These quadrangles are contained within the San Francisco, San Jose and Monterey 1 X 2 degree quadrangles, respectively. To avoid complication, the data in the table are broken out by the 30X60 minute quadrangle which contains them.

APPENDIX J

Descriptive Statistics and Statistical Comparison of Santa Clara County NURE Program eU Data, by 1X2 Degree Quadrangle

	All eU Data in San Francisco Quadrangle Portion of County	All eU Data in San Jose Quadrangle Portion of County	All eU Data in Monterey Quadrangle Portion of County
Size	2,732	9,956	1,068
Mean*	2.133	2.814	3.352
Std. Dev.*[1]	1.276	1.770	1.534
Std. Error*[2]	0.0244	0.0177	0.0469
C.I. of Mean*[3]	0.0479	0.0348	0.0921
Range*	10.0	21.6	10.1
Maximum*	10.2	21.7	10.2
Minimum*	0.1	0.1	0.1
Median*	2.0	2.5	3.2
25%*	1.2	1.4	2.2
75%*	2.8	3.9	4.2
Skewness	1.170	1.044	0.599
Kurtosis	2.914	3.503	0.578
K-S Dist.[4]	0.0711	0.0754	0.0658
K-S Prob.[5]	<0.001	<0.001	<0.001
SWilk W[6]	0.937	--	0.979
SWilk Prob.[7]	<0001	--	<0.001
Sum	5827.6	28014.1	3580.4
Sum of Squares	16879.6	110030.97	14513.44

*ppm
[1]Standard Deviation
[2]Standard Error of the Mean
[3]Confidence Interval for the Mean
[4]K-S Distance (The Kolmogorov-Smirnov distance)
[5]K-S Probability (The Kolmogorov-Smirnov probability)
[6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic)
[7]Shapiro-Wilk Probability

APPENDIX K

Mann-Whitney Rank Sum Test Comparisons of Santa Clara Radon Map Area eU Data for the San Francisco, San Jose and Monterey 1X2 Degree Quadrangles

Mann-Whitney Rank Sum Test					
eU Data Quadrangle	*N*	*Missing*	*Median*	*25%*	*75%*
San Francisco	2,732	0	2.0	1.2	2.8
San Jose	9,956	0	2.5	1.4	3.9
Result		Mann-Whitney U Statistic = 10622133.500 T = 14355411.500 n(small) = 2732 n(big) = 9956 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)			
San Francisco	2,732	0	2.0	1.2	2.8
Monterey	1,068	0	3.2	2.2	4.2
Result		Mann-Whitney U Statistic = 754965.500 T = 2733656.500 n(small) = 1068 n(big) = 2732 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P<0.001)			
San Jose	9,956	0	2.5	1.4	3.9
Monterey	1,068	0	3.2	2.2	4.2
Result		Mann-Whitney U Statistic = 4179321.500 T = 7024532.500 n(small) = 1068 n(big) = 9956 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)			

APPENDIX L

Mann-Whitney Rank Sum Test Comparisons of Santa Clara Radon Map Area eU Data by Preliminary Radon Potential Zone for the San Francisco, San Jose and Monterey 1X2 Degree Quadrangles

Mann-Whitney Rank Sum Test					
Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
For Santa Clara County eU Data from the San Francisco 1X2 Degree Quadrangle					
High Potential	135	0	2.0	1.1	2.8
Moderate Potential	877	0	2.3	1.5	3.1
Result		Mann-Whitney U Statistic = 51396.500 T = 60576.500 n(small) = 135 n(big) = 877 (P =0.014) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.014)			
High Potential	135	0	2.0	1.1	2.8
Low Potential	1436	0	1.9	1.2	2.7
Result		Mann-Whitney U Statistic = 91350.500 T = 111689.5 n(small) = 135 n(big) = 1436 (P = 0.268) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.268)			
Moderate Potential	877	0	2.3	1.5	3.1
Low Potential	1436	0	1.9	1.2	2.7
Result		Mann-Whitney U Statistic = 507863.000 T = 1136512.000 n(small) = 877 n(big) = 1436 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.001)			
High Potential	135	0	2.0	1.1	2.8
Unknown Potential	284	0	1.7	0.9	2.5
		Mann-Whitney U Statistic = 15893.500 T = 31626.500 n(small) = 135 n(big) = 284 (P = 0.005) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.005)			

Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
Moderate Potential	877	0	2.3	1.5	3.1
Unknown Potential	284	0	1.7	0.9	2.5
Result		Mann-Whitney U Statistic = 87304.500 T = 127774.500 n(small)=284 n(big) = 877 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P =< 0.001)			
Low Potential	1436	0	1.9	1.2	2.7
Unknown Potential	284	0	1.7	0.9	2.5
Result		Mann-Whitney U Statistic = 108765.500 T = 221235.500 n(small) = 284 n(big) = 1436 (P = 0.002) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.002)			
For Santa Clara County eU Data from the San Jose 1X2 Degree Quadrangle					
High Potential	99	0	2.1	1.4	3.5
Moderate Potential	1177	0	3.6	2.1	4.8
Result		Mann-Whitney U Statistic = 36870.000 T = 41820.000 n(small) = 99 n(big) = 1177 (P =<0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=< 0.001)			
High Potential	99	0	2.1	1.4	3.5
Low Potential	5643	0	2.2	1.3	3.6
Result		Mann-Whitney U Statistic = 273176.000 T = 278126.000 n(small) = 99 n(big) = 5643 (P = 0.707) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.707)			

Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
Moderate Potential	1177	0	3.6	2.1	4.8
Low Potential	5643	0	2.2	1.3	3.6
Result		Mann-Whitney U Statistic = 2208914.000 T = 5126150.000 n(small) = 1177 n(big) = 5643 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=< 0.001)			
High Potential	99	0	2.1	1.4	3.5
Unknown Potential	3037	0	2.8	1.7	4.1
Result		Mann-Whitney U Statistic = 122926.000 T = 127886.000 n(small) = 99 n(big) = 3037 (P = 0.002) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P= 0.002)			
Moderate Potential	1177	0	3.6	2.1	4.8
Unknown Potential	3037	0	2.8	1.7	4.1
Result		Mann-Whitney U Statistic = 1429555.500 T = 2838246.500 n(small) = 1177 n(big) = 3037 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=< 0.001)			
Low Potential	5643	0	2.2	1.3	3.6
Unknown Potential	3037	0	2.8	1.7	4.1
Result		Mann-Whitney U Statistic = 7270058.000 T = 14480936.000 n(small) = 3037 n(big) = 5643 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=< 0.001)			

Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
For Santa Clara County eU Data from the Monterey 1X2 Degree Quadrangle					
Low Potential	606	0	2.9	2.0	3.7
Unknown Potential	462	0	3.8	2.7	5.025
Result		Mann-Whitney U Statistic = 88563.5 T = 298361.500 n(small) = 462 n(big) = 606 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=< 0.001)			

APPENDIX M Santa Clara County Geology Units, Soil Units and Indoor-Radon Survey Data

HG = Hydrologic Group; Sh-Sw = Shrink-Swell, Med. = Median

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
101	Urban land, 0 to 2 % slopes, basins	manufactured layer	Qhaf (1) Qhfp (1)	-- high runoff	--	-- (98%)	2	0	0	1.0	1.5 0.5
102	Urban land, 0 to 2 % slopes, alluvial fans	manufactured layer	Qhaf (4) Qhfp (1)	-- high runoff	--	-- (98%)	5	1	20	1.6	6.2, 2.3, 1.6 1.1, 1.0
129	Urban land-Still complex, 2 to 5 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qpf (3)	-- A	-- M	-- (70%) >60 (25%)	3	1	33.3	1.0	6.5 1.0 0.8
130	Urban land-Still Complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhaf (10) Qhf2 (16) Qhl (4) Qpaf (3)	-- A	-- M	-- (70%) >60 (25%)	33	5	15.2	1.7	39.6, 16.1, 9.2, 7.6, 7.0, 3.6, 3.3, 2.4, 2.2, 2.1, 2.1 2.0, 2.0, 1.9, 1.8, 1.7, 1.7, 1.6, 1.6, 1.6, 1.5, 1.5 1.4, 1.4, 1.3, 1.2, 1.1, 1.1, 1.1, 1.0, 0.8, 0.6, 0.5

Soil Unit	**Soil Unit Name**	**Soil Parent Material**	**Geology Unit(s)**	**Soil HG**	**Sh-Sw**	**Inches depth to bedrock or restrictive layer (% of unit area)**	**N**	**N ≥ 4.0 pCi/L**	**% N ≥ 4.0 pCi/L**	**Med. pCi/L**	**Indoor Rn Data pCi/L**		
131	Urban land-Elpalalto complex, 0 to 2% slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhaf (29) Qhb (2) Qhf1 (4) Qhf2 (22) Qhfp (2) Qhl (25) Qht (1) Qpf (1)	-- C	-- M	-- (70%) >60 (23%)	86	9	10.5	1.5	19.0 9.7 9.0 6.4 5.5 5.4 4.7 4.5 4.1 3.4 3.2 3.2 3.2 3.1 3.1 2.8 2.7 2.6 2.6 2.6 2.5 2.4 2.4 2.3 2.3 2.3 2.2 2.1 2.1	2.0 2.0 2.0 1.8 1.8 1.7 1.7 1.7 1.7 1.6 1.6 1.6 1.6 1.5 1.5 1.5 1.4 1.4 1.4 1.4 1.4 1.3 1.3 1.3 1.2 1.2 1.2 1.1 1.1	1.1 1.1 1.1 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.8 0.8 0.8 0.8 0.8 0.8 0.7 0.7 0.7 0.7 0.6 0.6 0.6 0.6 0.5 0.5 0.4

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
135	Urban land-Stevens creek complex, 0 to 2% slopes	manufactured layer; alluvium derived from metamorphic and sedimentary rocks; metavolcanic rocks	Qhaf (25) Qhb (1) Qhf1 (1) Qhf2 (21) Qhfp (1) Qhl (1) Qhsc (1) Qpaf (19) Qpf (3)	-- C	-- M to H	-- (70%) > 60 (25%)	73	8	11.0	1.8	9.1 6.1 5.6 5.3 5.1 4.6 4.4 4.4 3.8 3.5 3.5 3.5 3.3 3.2 3.0 2.9 2.9 2.8 2.8 2.6 2.6 2.6 2.5 2.4 2.4	2.2 2.2 2.1 2.1 2.1 2.1 2.0 2.0 1.9 1.9 1.9 1.8 1.8 1.8 1.8 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.5	1.5 1.5 1.5 1.4 1.4 1.4 1.3 1.3 1.3 1.3 1.3 1.1 1.1 1.1 1.0 0.9 0.9 0.9 0.9 0.9 0.7 0.7 0.6 0.6

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
136	Urban land-Stevens creek complex, 2 to 9 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rocks and/or metavolcanic rocks	Qpaf (1) Qpf (1)	-- C	-- M to H	-- (68%) >60 (25%)	2	0	0	1.6	1.8 1.4		
140	Urban land-Flaskan complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rocks and/or metavolcanic rocks	Qhaf (4) Qhb (3) Qhf2 (20) Qhl (1) Qhsc (1) Qpaf (83) Qpf (58) QTsc (2)	-- C	-- L to M	-- (70%) >60 (20%)	172	14	8.1	1.5	15.1 14.9 7.4 6.8 6.1 5.1 5.0 4.8 4.8 4.7 4.6 4.1 4.1 4.0 3.9 3.6 3.5 3.4 3.4 3.4 3.2 3.0 3.0 3.1	1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.8 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.6 1.6 1.5	1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.1 1.0 1.0 1.0 1.0 1.0 1.0 1.0

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
140	Urban land-Flaskan complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rocks and/or metavolcanic rocks	Qhaf (4) Qhb (3) Qhf2 (20) Qhl (1) Qhsc (1) Qpaf (83) Qpf (58) QTsc (2)	-- C	-- L to M	-- (70%) >60 (20%)	172	14	8.1	1.5	2.9	1.5	1.0
											2.8	1.5	1.0
											2.7	1.5	0.9
											2.7	1.5	0.9
											2.6	1.5	0.9
											2.6	1.5	0.9
											2.6	1.5	0.9
											2.5	1.5	0.9
											2.5	1.5	0.9
											2.5	1.5	0.9
											2.4	1.5	0.9
											2.4	1.4	0.9
											2.4	1.4	0.9
											2.3	1.4	0.8
											2.3	1.4	0.8
											2.3	1.4	0.8
											2.2	1.4	0.8
											2.2	1.3	0.8
											2.2	1.3	0.8
											2.2	1.3	0.7
											2.2	1.3	0.7
											2.1	1.3	0.7
											2.1	1.3	0.7
											2.1	1.3	0.7
											2.1	1.3	0.7
											2.1	1.3	0.7
											2.1	1.3	0.7
											2.0	1.3	0.6
											2.0	1.3	0.6
											2.0	1.2	0.6
											1.9	1.2	0.6
											1.9	1.2	0.6
											1.9	1.2	0.5
											1.8		

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
141	Urban land-Flaskan complex, 2 to 9 % slopes	manufactured layer; alluvium derived from metamorphic and sedimentary rocks; metavolcanic rocks	Qpaf (3) Qpf (7) QTsc (2)	-- C	-- L to H	-- (70%) >60 (20%)	12	0	0	1.15	2.8 2.3 2.1 2.0 1.6 1.2	1.1 1.0 0.9 0.8 0.8 0.8	
145	Urbanland-Hangerone complex, 0 to 2 percent slopes, drained	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or metavolcanic rocks	fm (1) Qhaf (2) Qhb (65) Qhf2 (1) Qhfp (7) Qhl (2) Qpf (1)	-- C	-- H VH to H M to H	-- (70%) >60 (25%)	79	5	6.3	1.3	9.9 6.9 5.7 4.6 4.4 3.7 3.7 3.6 3.3 3.3 3.2 3.1 3.0 2.7 2.6 2.4 2.4 2.3 2.3 2.3 2.2 2.1 2.1 2.0 2.0 1.9 1.9	1.9 1.9 1.8 1.7 1.6 1.6 1.6 1.5 1.5 1.4 1.3 1.3 1.3 1.3 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.1	1.1 1.1 1.1 1.1 1.1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.9 0.9 0.9 0.9 0.9 0.8 0.8 0.7 0.7 0.7 0.7 0.6 0.5 0.4

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
146	Hangerone clay loam, drained, 0 to 2 % slopes	alluvium derived from metamorphic and sedimentary rocks and/or metavolcanic rock	Qhl (1)	-- C	H VH L M to H	20 to 40 (90%)	1	0	0	0.7	0.7		
150	Urban land-Embarcadero complex, 0 to 2 % slopes, drained	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhb (2)	-- C	-- H	-- (70%) 0 to 20 (25%)	2	1	50.0	5.1	9.2 1.0		
160	Urban land-Clear Lake complex, 0 to 2 percent slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhb (7) Qhf2 (3) Qhfp (6) Qhl (2) Qpaf (1)	-- C	-- VH	-- (65%) >60 (25%)	19	3	15.8	1.6	11.5 9.1 4.6 3.9 3.6 3.0 1.9	1.8 1.6 1.6 1.5 1.4 1.3	1.2 1.0 0.9 0.8 0.8 0.6

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
165	Urban land-Campbell complex, 0 to 2 percent slopes, protected	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhaf (3) Qhb (13) Qhf2 (19) Qhfp (9) Qhl (13) Qpaf (1) Qpf (1)	-- C	-- M H VH	-- (70%) >60 (20%)	59	8	13.6	1.7	14.1 7.7 7.1 6.1 5.7 5.7 5.5 4.7 3.5 3.4 3.3 3.0 3.0 2.9 2.8 2.8 2.6 2.6 2.6 2.3	2.3 2.2 2.0 1.9 1.8 1.8 1.8 1.7 1.7 1.7 1.6 1.6 1.6 1.5 1.5 1.5 1.5 1.4 1.3 1.3	1.3 1.3 1.3 1.2 1.2 1.2 1.1 1.1 1.1 1.1 1.1 1.0 1.0 0.9 0.9 0.8 0.7 0.6 0.6
169	Urban land-Elder complex, 0 to 2 % slopes, protected	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhf2 (4) Qhfp (1) Qhl (1)	-- A	-- L	-- (70%) >60 (20%)	6	0	0	2.05		3.2 2.4 2.1 2.0 1.9 1.3	

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
170	Urban land-Landelspark complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhaf (4) Qhb (1) Qhf1 (2) Qhf2 (10) Qhl (4) Qpaf (2) Qpf (2)	-- C	-- L 0 L	-- (70%) to 19” 19” to 23” 23” to 79” (20%)	25	3	12.0	1.4	7.3 5.9 5.4 3.5 3.1 2.1 2.0 1.9 1.8	1.8 1.7 1.5 1.4 1.4 1.3 1.2 1.2	1.1 1.1 1.0 1.0 1.0 0.9 0.9 0.7
175	Urban land-Botella complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhf2 (2) Qpaf (12) Qpf (2) QTsc (1)	-- C	-- L M	-- (75%) >60 (20%)	17	0	0	1.3	2.6 2.4 2.3 2.2 2.2 1.9	1.7 1.6 1.3 1.2 1.2 1.1	1.1 1.0 0.8 0.8 0.7
176	Urban land-Botella complex, 2 to 9 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qpaf (1) Qpf (5)	-- C	-- L M	-- (75%) >60 (20%)	6	0	0	1.4	2.7 2.2 1.7 1.1 1.0 0.8		
177	Urban land-Botella complex, 9 to 15 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhf1 (1) Qpf (2) QTp (1)	-- C	-- L M	-- (70%) >60 (20%)	4	0	0	0.8	2.2 0.9 0.7 0.4		

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L	
180	Urbanland-Newpark complex, 0 to 2 % slopes	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhb (6) Qhf2 (5) Qhl (1)	-- C	-- M	-- (70%) >60 (20%)	12	0	0	1.55	3.9 3.0 2.3 1.8 1.7 1.6	1.5 1.3 1.0 0.9 0.8 0.5
185	Urban Land-Bayshore complex, 0 to 2 % slopes, drained	manufactured layer alluvium derived from metamorphic and sedimentary rock and/or from metavolcanic rocks	Qhaf (1) Qhb (2) Qhf2 (1) Qhfp (1) Qhl (1)	-- C	-- M	-- (70%) >60 (20%)	6	0	0	1.05	3.1 1.6 1.3 0.8 0.8 0.7	
301	Montara sandy loam, 15 to 50 % slopes	residuum weathered from serpentinite and/or slope alluvium	Jsp (1) Tts (1)	-- D	-- D	rock outcrop 8 to 20 (75%)	2	0	0	1.1	1.2 1.0	
303	Montara-Santerhill complex, 15 to 30 % slopes	residuum weathered from serpentinite and/or slope alluvium residuum weathered from serpentinite and/or slope alluvium	fm (1)	D C	L VH H	8 to 20 (70%) 39 to 51 (20%	1	0	0	0.4	0.4	

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
305	Alo-Altamont complex, 15 to 30 percent slopes	residuum weathered from calcareous shale residuum weathered from calcareous shale	fm (1) Jsp (1) Qhf2 (2) Tm (1)	D C	H H to VH VH	20 to 40 (50%) 39 to 51 (35%)	5	0	0	0.8	2.0 0.9 0.8 0.7 0.5
306	Alo-Altamont complex, 30 to 50 % slopes	residuum weathered from calcareous shale residuum weathered from calcareous shale	Tms (2)	D C	H H	20 to 40 (60%) 39 to 51 (30%)	2	2	100.0	4.4	4.7 41
308	Urbanland-Santerhill-Montara complex, 9 to 15 % slopes	manufactured layer; residuum weathered from serpentinite residuum weathered from serpentinite	Jsp (1) KJk (1) Qhf2 (1)	-- C D	-- VH H L	-- (60%) 39 to 51 (25%) 8 to 20 (15%)	3	0	0	3.4	3.8 3.4 0.8
309	Urban land-Altamont-Alo complex, 9 to 15 % slopes	manufactured layer residuum weathered from calcareous shale residuum from calcareous shale	Qpf (1) Tsg (1)	-- C D	-- M to VH VH H	-- (60%) 39 to 51 (20%) 20 to 40 (15%)	2	0	0	0.75	1.0 0.5

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L	
312	Diablo-Urbanland complex, 9 to 15 % slopes	residuum weathered from calcareous shale manufactured layer	fg (2) QTsc (1) Tm (6) Tms_PA (1)	C	H	39 to 51 (60%) -- (40%)	10	3	30.0	2.4	16.2 10.9 4.0 3.2 2.5	2.3 2.3 1.4 11 1.0
313	Diablo-Urbanland complex, 15 to 30 % slopes	residuum from calcareous shale manufactured layer	Tlad (3) Tm (2)	C --	H --	>60 (60%) -- (40%)	5	1	20.0	3.6	4.5 3.9 3.6 3.2 1.1	
314	Urban land-Altamont-Alo complex, 15 to 30 percent slopes	manufactured layer residuum weathered from calcareous shale	Kbc (1) Qhf2 (1) Tcc (2)	-- C	-- M to VH VH	-- (60%) 39 to 51 (20%)	4	1	25.0	2.7	5.3 2.7 2.7 1.2	
316	Cropley clay, 2 to 9 % slopes	alluvium derived from calcareous shale	Qpaf (1) Tm (1)	C	H to VH	>60 (90%)	2	0	0	1.55	2.6 0.5	
317	Urban land-Cropley complex, 0 to 2 % slopes	manufactured layer alluvium derived from calcareous shale	Qhf1 (1) Qhf2 (2) Qpaf (2) Qpf (6) QTsc (1)	-- C	-- H to VH	-- (75%) >60 (25%)	12	0	0	1.7	2.3 2.3 2.1 1.9 1.9 1.8	1.6 1.4 1.4 1.4 1.2 1.1
318	Urban land-Cropley complex, 2 to 9 % slopes	manufactured layer alluvium derived from calcareous shale	Qhb (1) Qhf2 (2)	-- C	-- H	-- (75%) >60 ((25%)	3	1	33.3	3.0	6.4 3.0 0.9	

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
320	Literr-Merbeth complex, 15 to 30 % slopes	old, eroded alluvium old eroded alluvium	QTsc (1)	C C	M H M M	>60 (55%) >60 (35%)	1	0	0	1.3	1.3
322	Literr-Urban land-Merbeth complex, 15 to 30 % slopes	old, eroded alluvium manufactured layer old, eroded alluvium	Qpaf (1) QTsc (5)	C -- C	M H M -- L	>60 (55%) -- (30%) >60 (15%)	6	0	0	1.25	1.7 1.1 1.6 1.0 1.4 0.5
327	Literr-Urban land-Merbeth complex, 15 to 30 percent slopes	old, eroded alluvium manufactured layer old, eroded alluvium	QTsc (4)	C -- C	M H M -- M	>60 (55%) -- (30% >60 (15%)	4	0	0	1.25	2.0 1.5 1.0 0.8
330	Montavista clay loam, 15 to 30 % slopes	alluvium	Tm (1)	C	M H M	>60 (85%)	1	0	0	3.5	3.5

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
331	Urban land-Montavista complex, 15 to 30 % slopes	manufactured layer alluvium alluvium	Qpaf (1) QTsc (2)	-- C C	-- M H M L	-- (55%) >60 (25%) >60 (15%)	3	0	0	1.35	1.9 0.8 0.7		
332	Urban land-Montavista complex, 2 to 9 % slopes	manufactured layer alluvium alluvium	QTsc (1)	-- C C	-- M H M L	-- (55%) >60 (25%) >60 (15%)	1	0	0	2.0	2.0		
334	Urban Land-Montavista-Togasara complex, 9 to 15 % slopes	manufactured layer alluvium on hills/terraces alluvium on hills/terraces	fg (2) fm (1) Qpaf (1) Qpf (1) QTsc (9) Tm (1) Tms_PA (1)	-- C C	-- M H M L	-- (55%) >60 (25%) >60 (15%)	16	1	6.3	1.45	4.4 2.9 2.7 2.3 2.1 1.8	1.7 1.5 1.4 1.4 1.2	1.1 1.0 1.0 0.9 0.7

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L		
337	Urban Land-Togasara-Montavista complex, 2 to 9 % slopes	manufactured layer alluvium alluvium	Qhaf (5) Qpf (4) QTsc (6)	-- C C	-- L MHM	-- (55%) >60 (25%) >60 (15%)	15	0	0	1.4	2.5 2.3 2.1 1.9 1.7	1.5 1.5 1.4 1.4 1.4	1.2 1.0 0.8 0.7 0.6
350	Urban land-Togasara-Montavista complex, 15 to 30 percent slopes	manufactured layer alluvium alluvium	Qpf (1) QTsc (3)	-- C C	--	-- (55%) >60 (20%) >60 (15%)	4	0	0	0.75	1.1 0.9 0.6 0.4		
371	Zeppelin-Mccoy complex, 15 to 30 % slopes	residuum weathered from sandstone residuum weathered from sandstone	fg (1) Qpaf (1) Tm (4)	D C	MH MH	37 to 40 (45%) 20 to 40 (40%)	6	2	33.3	2.45	11.7 9.1 2.8	2.1 1.6 1.3	
375	Alumrock-Zepplin complex, 15 to 30 % slopes	residuum weathered from sandstone residuum weathered from sandstone	fg (2) Tm (1)	C C	L M	37 to 40 (45%) 20 to 40 (40%)	3	1	33.3	2.5	6.2 2.5 2.3		
376	Zeppelin-Alumrock complex, 30 to 50 % slopes	residuum from weathered sandstone residuum from weathered sandstone	Tma (4) Tus (2)	C C	L M	20 to 40 (50%) 39 to 61 (30%)	6	2	33.3	2.6	5.7 5.2 2.9	2.3 1.7 1.2	

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
377	Alumrock fine sandy loam, 15 to 30 percent slopes	residuum from weathered sandstone residuum from weathered sandstone	Tms (3)	C C	L M	20 to 40 (85%) 39 to 61 (10%)	3	0	0	2.2	2.5 2.2 1.8
516	Ben Lomond gravelly sandy loam, 15 to 30 % slopes	residuum weathered from sandstone	Jbk? (1) Qls (1) Tu (2)	A	M	39 to 55 (80%)	4	2	50.0	3.8	18.8 5.4 2.2 1.1
517	Ben Lomond-Casrock complex, 30 to 50 % slopes	residuum weathered from sandstone residuum weathered from sandstone	Qls (1) Tsl (4)	A B	M L	39 to 55 (65%) 20 to 40 (20%)	5	4	80.0	4.4	24.5 9.8 4.4 4.1 2.7
518	Ben Lomond-Casrock complex, 50 to 75 % slopes	slope alluvium derived from sandstone slope alluvium derived from sandstone	Tsl (1)	A B	M L	39 to 55 (65%) 20 to 40 (20%)	1	0	0	1.9	1.9
519	Ben Lomond-Felton complex, 30 to 75 percent slopes	residuum weathered from sandstone residuum weathered from sandstone	Tsl (1)	A B	M M	39 to 55 (45%) >60 (35%)	1	1	100.0	8.5	8.5

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
551	Maymen-Katykat complex, 8 to 30 % slopes	colluvium derived from shale and/or residuum weathered from shale colluvium derived from sandstone and/or colluvium derived from mudstone and residuum weathered from each	fms (1)	D C	L L	6 to 20 (35%) 39 to 60 (20%)	1	0	0	3.4	3.4
560	Katykat-Mouser-Sanikara complex, 30 to 50 % slopes	residuum weathered from serpentinite and/or slope alluvium colluvium derived from sandstone colluvium derived from greywacke and/or residuum weathered from graywacke	fms (1)	C B D	M M M	39 to 60 (40%) <60 10 to 20 (15%)	1	0	0	3.7	3.7

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
566	Mouser-Katykat-Sanikara complex, 50 to 75 % slopes	colluvium derived from sandstone and/or residuum weathered from sandstone	fms (1)	B	L	>60 (40%)	1	0	0	3.1	3.1
		colluvium derived from mudstone and/or sandstone and or residuum of each		D	L	>60 (30%)					
		colluvium derived from greywacke and/or residuum weathered from graywacke		D	L	10 to 20 (30%)					
569	Katykat-Sanikara complex, 8 to 30 % slopes	colluvium derived from mudstone and/or sandstone and or residuum of each	fms (1)	C	L	39 to 60 (60%)	1	1	100.0	24.5	24.5
		colluvium derived from greywacke and/or residuum weathered from graywacke		D	L	10 to 20 (20%)					
		colluvium derived from sandstone and/or residuum weathered from sandstone		B	L	>60 (15%)					

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
AcE	Altamont clay, 15 to 30 % slopes	well-drained clays underlain by sedimentary rocks located on uplands	Qls (1)	D	H	30 to 60	1	0	0	0.9	0.9
ArA	Arbuckle gravelly loam, 0 to 2 % slopes	well-drained gravelly loams in alluvium derived from sedimentary rock on fans and terraces	Qhl (1) Qpf (1)	B	M L	48	2	0	0	0.65	0.9 0.4
Ca	Campbell silty clay loam (< 1 % slope)	somewhat poorly drained silty clay loams in alluvium from sedimentary rock; on low valley bottoms and alluvial plains	Qpf (1)	C	M	>60	1	0	0	2.0	2.0
CrA	Cropley clay, 0 to 2 % slopes	well-drained clays underlain by alluvium from mixed sources on fans and terraces	Qhf2 (1)	D	H	>60	1	0	0	1.0	1.0
GoF	Gilroy, 30 to 50 % slopes (?)	weathered basic igneous bedrock on uplands	Qa (1)	C	M	24	1	0	0	0.8	0.8
HfC	Hillgate silt loam, 2 to 9 % slopes	well-drained silt loams in alluvial materials from mixed sources; on terraces	Qpf (1)	D	M H M	>60	1	0	0	0.9	0.9
LfF	Los Gatos gravelly loam, 30 to 50 percent slopes	well-drained gravelly loams on uplands underlain by meta shale at 25 to 50 inches	Qpf (1)	B/C	M M	24 to 48	1	0	0	2.1	2.1

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
LoE	Los Osos clay loam, 15 to 30 % slopes (on uplands)	well drained clay loams underlain by sedimentary rock at 26 to 40 inches	Qpf (1)	C	M H	24 to 42	1	0	0	1.8	1.8
LoF	Los Osos clay loam, 30 to 50 % slopes (on uplands)	well drained clay loams underlain by sedimentary rock at 26 to 40 inches	Tms (3)	C	M H	24 to 42	3	1	33.3	2.8	5.4 2.8 1.4
PoA	Pleasanton loam, 0 to 2 % slopes	well-drained loams underlain by old gravelly sedimentary alluvium; on fans and terraces	Qpf (8)	B	M	>60	8	1	12.5	1.65	8.6 1.6 3.8 1.1 2.7 1.1 1.7 0.5
PpA	Pleasanton gravelly loam, 0 to 2% slopes	well-drained loams underlain by old gravelly sedimentary alluvium; on fans and terraces	Qhf2 (1) Qpf (1)	B	M	>60	2	0	0	2.5	3.2 1.8
SdA	San Ysidro, 0 to 2 % slopes	old alluvium from material derived from sedimentary rock on fans and terraces	Qhf2 (1) Qpf (1)	D	M H M	>60	2	0	0	1.8	2.0 1.6
SfA	San Ysidro, Acid Variant, 0 to 2 % slopes (pH 6.0)	old alluvium from material derived from sedimentary rock on fans and terraces	Qa (1) Qpf (1)	D	M H M	>60	2	0	0	1.65	2.1 1.2
SfC	San Ysidro loam, acid variant, 2 to 9 % slopes	moderately well drained loams in old alluvium from sedimentary rock; on fans and terraces; strongly acid subsoil	Qpf (1)	D	M H M	>60	1	0	0	2.3	2.3

Soil Unit	Soil Unit Name	Soil Parent Material	Geology Unit(s)	Soil HG	Sh-Sw	Inches depth to bedrock or restrictive layer (% of unit area)	N	N ≥ 4.0 pCi/L	% N ≥ 4.0 pCi/L	Med. pCi/L	Indoor Rn Data pCi/L
VaE2	Vallecitos rocky loam, 15 to 30 % slopes	steeper soils on hills; some areas may have serpentinite at ≥ 4 feet deep	Qpaf1 (1)	C	M H	22+	1	0	0	1.7	1.7
YaA	Yolo loam, 0 to 2 % slopes	well-drained loams underlain by alluvium from sedimentary rock on alluvial plains and fans	Qhfp (4)	B	M M	>60	4	0	0	1.2	2.3 1.3 1.1 0.8
ZbA	Zamora clay loam, 0 to 2 % slopes	well drained clay loams underlain by alluvium of mixed origin on alluvial fans	Qhf2 (1) Qhl (1)	B	M	>60	2	0	0	1.55	2.4 0.7
	test totals						793	82	10.34	1.6	

APPENDIX N

Descriptive Statistics for Indoor-Radon Data (untransformed) by Santa Clara County Radon Potential Zone and Soils With and Without a Manufactured Layer Horizon (MLH)

	All Indoor-Radon Data		High Zone Radon Data		Moderate Zone Radon Data		Low Zone Radon Data		Unknown Zone Radon Data	
	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Size	712	81	33	27	403	2	265	43	11	9
Mean*	2.160	3.375	3.594	4.930	2.445	1.4	1.544	1.83	2.273	6.533
Std. Dev.*[1]	2.438	4.432	3.331	4.827	2.911	0.99	0.832	1.386	2.837	8.791
Std. Error*[2]	0.0914	0.492	0.580	0.929	0.145	0.7	0.0511	0.211	0.855	2.93
C.I. of Mean*[3]	0.179	0.980	1.181	1.909	0.285	8.894	0.101	0.426	1.906	6.758
Range*	39.2	24.1	14.2	23.7	39.2	1.4	6.7	8.2	8.7	23.6
Maximum*	39.6	24.5	15.1	24.5	39.6	2.1	7.1	8.6	9.1	24.5
Minimum*	0.4	0.4	0.9	0.8	0.4	0.7	0.4	0.4	0.4	0.9
Median*	1.55	2.1	2.3	3.5	1.7	1.4	1.4	1.6	1.2	2.2
25%*	1.1	1.15	1.3	2.2	1.2	0.7	1.0	1.0	0.8	1.15
75%*	2.3	3.45	4.65	5.7	2.6	2.1	1.9	2.3	2.2	12.1
Skewness	7.258	3.447	2.054	2.829	6.839	--	1.864	2.939	1.976	1.637
Kurtosis	86.917	13.137	4.302	10.112	71.374	--	7.232	12.918	2.994	1.282
K-S Dist.[4]	0.243	0.259	0.209	0.214	0.251	0.26	0.123	0.158	0.348	0.335
K-S Prob.[5]	<0.001	<0.001	<0.001	0.003	<0.001	0.481	<0.001	0.009	<0.001	0.004
SWilk W[6]	0.489	0.570	0.746	0.704	0.482	--	0.867	0.745	0.662	0.682
SWilk Prob.[7]	<0.001	<0.001	<0.001	<0.001	<0.001	--	<0.001	<0.001	<0.001	<0.001
Sum	1538.1	273.1	118.6	133.1	985.4	2.8	409.1	78.8	25.0	58.8
Sum of Squares	7547.97	2493.88	781.3	1261.87	5814.92	4.9	814.43	224.67	137.32	1002.44

*pCi/L; [1]Standard Deviation; [2]Standard Error of the Mean; [3]Confidence Interval for the Mean; [4]K-S Distance (The Kolmogorov-Smirnov distance); [5]K-S Probability (The Kolmogorov-Smirnov probability); [6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic); [7]Shapiro-Wilk Probability

APPENDIX O

Percentages of ≥ 4.0 pCi/L Radon Survey Data by Preliminary Radon Potential Zone and Presence or Absence of Soils With a Manufactured Layer Horizon (MLH) in Santa Clara County

	All Data	All Data	High Pot.**	High Pot.	Mod.^ Pot.	Mod. Pot.	Low Pot.	Low Pot.	Unkn.^^ Pot.	Unkn. Pot.
Data	MLH*	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Number of data	712	81	33	27	403	2	265	43	11	9
Number of data ≥ 4.0 pCi/L	65	17	11	13	50	0	2	1	2	3
Percent ≥ 4.0 pCi/L data	9.1	21.0	33.3	48.0	12.4	0.0	0.75	2.3	18.2	33.3

*MLH = Manufactured Layer Horizon soil (urban development) area; **Pot. = radon potential; ^Mod. = moderate; ^^Unkn. = unknown

APPENDIX P

Descriptive Statistics for eU Data (untransformed) by Santa Clara County-San Francisco 1X2 Degree Quadrangle Radon Potential Zone and Soils With and Without a Manufactured Layer Horizon (MLH)

	All eU Data		**High Zone eU Data**		**Moderate Zone eU Data**		**Low Zone eU Data**		**Unknown Zone eU Data**	
	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Size	1466	1266	26	109	817	60	603	833	20	264
Mean*	2.407	1.816	1.735	2.207	2.406	2.510	2.458	1.732	1.815	1.761
Std. Dev.*[1]	1.327	1.136	0.816	1.240	1.298	1.264	1.374	1.099	1.289	1.091
Std. Error*[2]	0.0347	0.0319	0.160	0.119	0.0454	0.163	0.0560	0.0381	0.288	0.0671
C.I. of Mean*[3]	0.0680	0.0626	0.330	0.235	0.0891	0.327	0.110	0.0748	0.603	0.132
Range*	10.1	6.8	3.3	5.1	8.8	5.2	10.1	6.8	5.3	4.7
Maximum*	10.2	6.9	3.5	5.2	8.9	5.3	10.2	6.9	5.8	4.8
Minimum*	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.5	0.1
Median*	2.3	1.65	1.6	2.1	2.3	2.55	2.3	1.6	1.4	1.7
25%*	1.5	0.9	1.075	1.15	1.5	1.6	1.5	0.9	0.925	0.9
75%*	3.1	2.5	2.275	3.0	3.0	3.2	3.1	2.3	2.3	2.5
Skewness	1.308	0.869	0.281	0.353	1.205	0.169	1.411	1.139	1.732	0.434
Kurtosis	3.585	0.784	-0.422	-0.710	3.121	-0.364	4.049	1.861	3.670	-0.560
K-S Dist.[4]	0.0791	0.0840	0.104	0.0736	0.0794	0.0740	0.0820	0.0915	0.183	0.0762
K-S Prob.[5]	<0.001	<0.001	0.607	0.152	<0.001	0.532	<0.001	<0.001	0.077	<0.001
SWilk W[6]	0.927	0.950	0.981	0.967	0.934	0.976	0.918	0.930	0.831	0.965
SWilk Prob.[7]	<0.001	<0.001	0.885	0.008	<0.001	0.298	<0.001	<0.001	0.003	<0.001
Sum	3529.1	2298.5	45.1	240.6	1965.3	150.6	1482.4	1442.4	36.3	464.9
Sum of Squares	11075.17	5804.43	94.89	697.14	6101.35	472.28	4781.46	3503.38	97.47	1131.63

*ppm; [1]Standard Deviation; [2]Standard Error of the Mean; [3]Confidence Interval for the Mean; [4]K-S Distance (The Kolmogorov-Smirnov distance); [5]K-S Probability (The Kolmogorov-Smirnov probability); [6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic); [7]Shapiro-Wilk Probability

APPENDIX Q

Percentages of ≥ 5.0 ppm NURE eU Survey Data by Preliminary Radon Potential Zone and Presence or Absence of Soils With a Manufactured Horizon (MLH) Within the San Francisco 1X2 Degree Quadrangle in Santa Clara County

	All Data	All Data	High Pot.**	High Pot.	Mod.^ Pot.	Mod. Pot.	Low Pot.	Low Pot.	Unkn.^^ Pot.	Unkn. Pot.
Data	MLH*	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Number of data	1466	1266	26	109	817	60	603	833	20	264
Number of data ≥ 4.0 pCi/L	64	18	0	1	38	3	25	14	1	0
Percent ≥ 4.0 pCi/L data	4.4	1.42	0.0	0.9	4.7	5.0	4.2	1.7	5.0	0.0

*MLH = Manufactured Layer Horizon soil (urban development) area; **Pot. = radon potential; ^Mod. = moderate; ^^Unkn. = unknown

APPENDIX R

Descriptive Statistics for NURE eU Data (untransformed) by Santa Clara County-San Jose 1X2 Degree Quadrangle Radon Potential Zone and Soils With and Without a Manufactured Layer Horizon (MLH)

	All eU Data		**High Zone eU Data**		**Moderate Zone eU Data**		**Low Zone eU Data**		**Unknown Zone eU Data**	
	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Size	2688	7633	1	98	1016	161	1405	4587	266	2787
Mean*	3.624	2.530	2.0	2.47	3.654	3.646	3.540	2.277	3.962	2.884
Std. Dev.*[1]	1.955	1.589	--	1.56	2.12	1.719	1.818	1.464	1.964	1.683
Std. Error*[2]	0.0377	0.0182	--	0.158	0.0665	0.135	0.0485	0.0216	0.120	0.0319
C.I. of Mean*[3]	0.0739	0.0357	--	0.131	0.131	0.368	0.0951	0.0424	0.237	0.0625
Range*	20.6	21.6	0.0	6.4	20.6	8.4	10.0	21.6	8.8	10.6
Maximum*	20.7	21.7	2.0	6.5	20.7	8.6	10.1	21.7	8.9	10.7
Minimum*	0.1	0.1	2.0	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Median*	3.6	2.3	2.0	2.1	3.6	3.9	3.6	2.0	4.2	2.7
25%*	2.1	1.3	2.0	1.4	2.1	2.15	2.1	1.2	2.3	1.6
75%*	4.9	3.5	2.0	3.5	4.8	4.7	4.9	3.1	5.3	3.9
Skewness	0.807	1.061	--	0.828	1.54	0.0955	0.125	1.333	-0.00441	0.768
Kurtosis	3.683	3.424	--	0.0851	7.485	-0.408	-0.642	7.244	-0.609	0709
K-S Dist.[4]	0.0401	0.0784	--	0.104	0.0600	0.0794	0.0507	0.0838	0.0608	0.0653
K-S Prob.[5]	<0.001	<0.001	--	0.011	<0.001	0.015	<0.001	<0.001	0.019	<0.001
SWilk W[6]	0.959	--	--	0.932	0.916	0.980	0.983	0.929	0.960	0.962
SWilk Prob.[7]	<0.001	--	--	<0.001	<0.001	0.020	<0.001	<0.001	<0.001	<0.001
Sum	9742.0	19310.9	2.0	242.1	3712.4	587.0	4973.7	10443.8	1053.9	5197.55
Sum of Squares	45574.48	68129.63	4.0	834.25	18127.86	2613.06	22245.07	33605.6	8038.0	31076.72

*ppm; [1]Standard Deviation; [2]Standard Error of the Mean; [3]Confidence Interval for the Mean; [4]K-S Distance (The Kolmogorov-Smirnov distance); [5]K-S Probability (The Kolmogorov-Smirnov probability); [6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic); [7]Shapiro-Wilk Probability

APPENDIX S

Percentages of ≥ 5.0 ppm NURE eU Data by Preliminary Radon Potential Zone and Presence or Absence of Soils With a Manufactured Layer Horizon (MLH) Within the San Jose 1X2 Degree Quadrangle in Santa Clara County

	All Data	All Data	High Pot.**	High Pot.	Mod.^ Pot.	Mod. Pot.	Low Pot.	Low Pot.	Unkn.^^ Pot.	Unkn. Pot.
Data	MLH*	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH	MLH	no MLH
Number of data	2688	7633	1	98	1016	161	1405	4587	266	2787
Number of data ≥ 4.0 pCi/L	661	585	0	10	233	31	344	233	84	311
Percent ≥ 4.0 pCi/L data	24.6	7.7	0.0	10.2	22.9	19.3	24.5	5.1	31.6	11.2

*MLH = manufactured layer horizon soil (urban development) area; **Pot. = radon potential; ^Mod. = moderate; ^^Unkn. = unknown

APPENDIX T

Mann-Whitney Rank Sum Test Comparisons of Santa Clara Radon (Rn) Map Area Radon Survey Data and Manufactured Layer Horizon (MLH) Soil Areas

Mann-Whitney Rank Sum Test					
Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
For Santa Clara County Indoor-Radon Survey Data					
All Rn survey data from areas with soils with MLH	712	0	1.55	1.1	2.3
All Rn survey data from non-MLH soil areas	81	0	2.1	1.15	3.45
Result		Mann-Whitney U Statistic = 23445.500 T = 37547.500 n(small) = 81 n(big) = 712 (P =0.006) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.006)			
High Potential-Rn data from MLH soil areas	33	0	2.3	1.3	4.65
High Potential-Rn data from non-MLH soil areas	27	0	3.5	2.2	5.7
Result		Mann-Whitney U Statistic = 340.000 T = 929.000 n(small) = 27 n(big) = 33 (P = 0.119) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.119)			
Moderate Potential-Rn data from MLH soil areas	403	0	1.7	1.2	2.6
Moderate Potential-Rn data from non-MLH soil areas	2*	0	1.4	0.7	2.1
Result		Mann-Whitney U Statistic = 277.000 T = 280.000 n(small) = 2 n(big) = 403 (P =< 0.447) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.447)* ***N data in moderate potential areas without a MLH is too small for a meaningful statistical comparison**			

APPENDIX __ continued					
Rn Areas Compared	*N*	*Missing*	*Median pCi/L*	*25% pCi/L*	*75% pCi/L*
Low Potential-Rn data from MLH soil areas	265	0	1.4	1.0	1.9
Low Potential-Rn data from non-MLH soil areas	43	0	1.6	1.0	2.3
Result		Mann-Whitney U Statistic = 5115.000 T = 7226.000 n(small) = 43 n(big) = 265 (P = 0.282) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.282)			
Unknown Potential-Rn data from MLH soil areas	11*	0	1.2	0.8	2.2
Unknown Potential-Rn data from areas non-MLS soil areas	9*	0	2.2	1.15	12.1
		Mann-Whitney U Statistic = 27.00 T = 117.000 n(small) = 9 n(big) = 11 (P =0.094) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.094)* ***N data in unknown potential areas with and without a MLH is too small for a meaningful statistical comparison**			

APPENDIX U

Mann-Whitney Rank Sum Test Comparisons of Santa Clara Radon Map Area NURE eU Data and Areas With and Without Soils Having a Manufactured Layer Horizon (MLH) Note--column *N*, * = number of data too small for a meaningful statistical comparison

Mann-Whitney Rank Sum Test					
Rn Areas Compared	*N*	*Missing*	*Median ppm*	*25% ppm*	*75% ppm*
For Santa Clara County eU Data from the San Francisco 1X2 Degree Quadrangle					
All eU NURE survey data from areas MLH soils	1466	0	2.3	1.5	3.1
All Rn survey data from areas with non-MLH soils	1266	0	1.65	0.9	2.5
Result		Mann-Whitney U Statistic = 667956.000 T = 1469967.000 n(small) = 1266 n(big) = 1466 (P =0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.001)			
High Potential-eU data from MLH soil areas	26	0	1.6	1.075	2.275
High Potential-eU data from non-MLH soil areas	109	0	2.1	1.150	3.0
Result		Mann-Whitney U Statistic = 1125.000 T = 1476.500 n(small) = 26 n(big) = 109 (P = 0.104) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=0.104)			
Moderate Potential-Rn data from MLH soil areas	817	0	2.3	1.5	3.0
Moderate Potential-Rn data from non-MLH soil areas	60	0	2.55	1.6	3.1
Result		Mann-Whitney U Statistic = 22466.000 T = 29384.000 n(small) = 60 n(big) = 817 (P =< 0.280) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=<0.280)			
APPENDIX continues					

Mann-Whitney Rank Sum Test					
Rn Areas Compared	*N*	*Missing*	*Median ppm*	*25% ppm*	*75% ppm*
For Santa Clara County eU Data from the San Francisco 1X2 Degree Quadrangle					
Low Potential-Rn data from MLH soil areas	603	0	2.3	1.5	3.1
Low Potential-Rn data from non-MLH soil areas	833	0	1.6	0.9	2.3
Result		Mann-Whitney U Statistic = 164199.000 T = 520602.000 n(small) = 603 n(big) = 833 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.0.001)			
Unknown Potential-Rn data from MLH soil areas	20*	0	1.4	0.925	2.3
Unknown Potential-Rn data from non-MLH soil areas	264	0	1.7	0.9	2.5
Result		Mann-Whitney U Statistic = 2589.000 T = 2799.000 n(small) = 20 n(big) = 264 (P =< 0.887) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=<0.887)			
For Santa Clara County eU Data from the San Jose 1X2 Degree Quadrangle					
All eU NURE survey data from MLH soil areas	2688)	0	3.6	2.1	4.9
All Rn survey data from areas with non-MLH soil areas	7633	0	2.3	1.3	3.5
Result		Mann-Whitney U Statistic = 6727333.5 T = 17404186.5 n(small) = 2688 n(big) = 7633 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.0.001)			
APPENDIX continues					

Mann-Whitney Rank Sum Test					
Rn Areas Compared	*N*	*Missing*	*Median ppm*	*25% ppm*	*75% ppm*
High Potential-eU data from MLH soil areas	1*	0	2.0	2.0	2.0
High Potential-eU data from non-MLH soil areas	98	0	2.1	1.4	3.5
Result		Mann-Whitney U Statistic = 46.000 T = 47.000 n(small) = 1 n(big) = 98 (P =< 0.930) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=<0.930)			
Moderate Potential-Rn data from MLH soil areas	1016	0	3.6	2.1	4.8
Moderate Potential-Rn data from non-MLH soil areas	161	0	3.9	2.15	4.7
Result		Mann-Whitney U Statistic = 79236.500 T = 97380.500 n(small) = 161 n(big) = 1016 (P =< 0.524) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P=<0.524)			
Low Potential-Rn data from MLH soil areas	1405	0	3.6	2.1	4.9
Low Potential-Rn data from non-MLH soil areas	4587	0	2.0	1.2	3.1
Result		Mann-Whitney U Statistic = 1899391.500 T = 5533058.500 n(small) = 1405 n(big) = 4587 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.0.001)			
Unknown Potential-Rn data from MLH soil areas	266	0	4.2	2.3	5.3
Unknown Potential-Rn data from non-MLH soil areas	2787	0	2.7	1.6	3.9
Result		Mann-Whitney U Statistic = 247298.000 T = 529555.000 n(small) = 266 n(big) = 2787 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=<0.0.001)			

APPENDIX V

Descriptive Statistics and Statistical Comparison of Indoor-Radon Data (untransformed) by Santa Clara County Radon Potential Zone

	All Indoor-Radon Data	High Zone Radon Data	Moderate Zone Radon Data	Low Zone Radon Data	Unknown Zone Radon Data
Size	793	60	405	308	20
Mean*	2.284	4.195	2.440	1.584	4.190
Std. Dev.*[1]	2.730	4.091	2.905	0.932	6.443
Std. Error*[2]	0.0970	0.528	0.144	0.0531	1.441
C.I. of Mean*[3]	0.190	1.057	0.284	0.104	3.015
Range*	39.2	23.7	39.2	8.2	24.1
Maximum*	39.6	24.5	39.6	8.6	24.5
Minimum*	0.4	0.8	0.4	0.4	0.4
Median*	1.6	2.8	1.7	1.4	1.35
25%*	1.1	1.625	1.2	1.0	0.825
75%*	2.4	5.35	2.6	2.0	4.725
Skewness	6.321	2.725	6.851	2.566	2.452
Kurtosis	60.667	9.956	71.650	13.418	5.588
K-S Dist.[4]	0.249	0.203	0.251	0.117	0.341
K-S Prob.[5]	<0.001	<0.001	<0.001	<0.001	<0.001
SWilk W[6]	0.488	0.718	0.482	0.817	0.605
SWilk Prob.[7]	<0.001	<0.001	<0.001	<0.001	<0.001
Sum	1811.5	251.7	98802	487.8	83.8
Sum of Squares	10041.85	2043.17	5819.82	1039.10	1139.76

*pCi/L
[1]Standard Deviation
[2]Standard Error of the Mean
[3]Confidence Interval for the Mean
[4]K-S Distance (The Kolmogorov-Smirnov distance)
[5]K-S Probability (The Kolmogorov-Smirnov probability)
[6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic)
[7]Shapiro-Wilk Probability

APPENDIX W

Descriptive Statistics and Statistical Comparison of Indoor-Radon Data (Ln-transformed) by Santa Clara County Radon Potential Zone

	All Indoor-Radon Data	High Zone Radon Data	Moderate Zone Radon Data	Low Zone Radon Data	Unknown Zone Radon Data
Size	793	60	405	308	20
Mean*	0.536	1.105	0.609	0.321	0.692
Std. Dev.*[1]	0.678	0.789	0.672	0.523	1.146
Std. Error*[2]	0.0241	0.102	0.0334	0.0298	0.256
C.I. of Mean*[3]	0.0473	0.204	0.0656	0.0586	0.536
Range*	4.595	3.422	4.595	3.068	4.115
Maximum*	3.679	3.199	3.679	2.152	3.199
Minimum*	-0.916	-0.223	-0.916	-0.916	-0.916
Median*	0.470	1.030	0.531	0.336	0.299
25%*	0.0953	0.485	0.182	0.000	-0.194
75%*	0.875	1.677	0.956	0.693	1.513
Skewness	0.874	0.408	0.886	0.124	0.892
Kurtosis	1.512	-0.366	1.429	-0.0420	0.0734
K-S Dist.[4]	0.0751	0.0716	0.0877	0.0596	0.172
K-S Prob.[5]	<0.001	0.579	<0.001	0.010	0.123
SWilk W[6]	0.960	0.974	0.959	0.991	0.915
SWilk Prob.[7]	<0.001	0.235	<0.001	0.070	0.081
Sum	425.412	66.320	246.514	98.741	13.837
Sum of Squares	592.335	110.002	332.273	115.548	34.512

*pCi/L
[1]Standard Deviation
[2]Standard Error of the Mean
[3]Confidence Interval for the Mean
[4]K-S Distance (The Kolmogorov-Smirnov distance)
[5]K-S Probability (The Kolmogorov-Smirnov probability)
[6]Shapiro-Wilk W (The Shapiro-Wilk W-statistic)
[7]Shapiro-Wilk Probability

APPENDIX X

Results of the Shapiro-Wilk Normality Test for Untransformed and Ln-Transformed Indoor-Radon Data, by Radon Potential Zone

Data	N	W-Statistic*	P	Result
All Data-Untransformed	793	0.488	<0.001	Failed
All Data-Ln Transformed	793	0.960	<0.001	Failed
High Zone-Untransformed	60	0.718	<0.001	Failed
High Zone-Ln Transformed	60	0.974	=0.235	Passed
Moderate Zone-Untransformed	405	0.482	<0.001	Failed
Moderate Zone-Ln Transformed	405	0.959	<0.001	Failed
Low Zone-Untransformed	308	0.817	<0.001	Failed
Low Zone-Ln Transformed	308	0.991	=0.070	Passed
Unknown Zone-Transformed	20	0.605	<0.001	Failed
Unknown Zone-Ln Transformed	20	0.915	=0.081	Passed

*Shapiro-Wilk Statistic (W)—tests the null hypothesis that the data were sampled from a normal distribution. Small values of W indicate a departure from normality (SigmaPlot®12 Statistics User's Guide part 2, Systat Software, Inc., p. 23)

A test that fails indicates that the data vary significantly from the pattern expected if the data were drawn from a population with a normal distribution.

A test that passes indicated that the data match the pattern expected if the data were drawn from a population with a normal distribution.

APPENDIX Y

Mann-Whitney Rank Sum Test Comparisons of Indoor-Radon Data Between the High, Moderate, Low and Unknown Radon Potential Zones

Mann-Whitney Rank Sum Test					
Group	*N*	*Missing*	*Median*	*25%*	*75%*
High Zone	60	0	2.8	1.625	5.350
Moderate Zone	405	0	1.7	1.2	2.6
Result		Mann-Whitney U Statistic = 7659.500 T = 18470.500 n(small) = 60 n(big) = 405 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P<0.001)			
High Zone	60	0	2.8	1.625	5.350
Low Zone	308	0	1.4	1.0	2.0
Result		Mann-Whitney U Statistic = 3921.000 T = 16389.000 n(small) = 60 n(big) = 308 (P =< 0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P<0.001)			
High Zone	60	0	2.1	1.625	5.350
Unknown Zone	20	0	1.35	0.825	4.725
Result		Mann-Whitney U Statistic = 411.000 T = 621.000 n(small) = 20 n(big) = 60 (P = 0.036) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.036)			
Moderate Zone	405	0	1.7	1.2	2.6
Low Zone	308	0	1.4	1.0	2.0
Result		Mann-Whitney U Statistic = 47843.500 T = 95429.500 n(small) = 308 n(big) = 405 (P =<0.001) The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P=0.001)			
		APPENDIX Y continues on next page			

Mann-Whitney Rank Sum Test					
Group	*N*	*Missing*	*Median*	*25%*	*75%*
Moderate Zone	405	0	1.7	1.2	2.6
Unknown Zone	20	00	1.35	0.825	4.725
Result		Mann-Whitney U Statistic = 3790.000 T = 4000.000 n(small) = 20 n(big) = 405 (P = 0.628) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.628)			
Low Zone	308	0	1.4	1.0	2.0
Unknown Zone	20	0	1.35	0.825	4.725
Result		Mann-Whitney U Statistic = 2726.000 T = 3643.500 n(small) = 20 n(big) = 308 (P = 0.390) The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.328)			